

CycSight

Designing A Haptic Wristband with A Detachable Radar to Improve Hearing-impaired Cyclists' Road Safety

Master of Industrial Design Project by
Siran Liao, B.E.
July 2020

Advisor:
Jon A Sanford
Professor, School of Industrial Design

Committee:
Leila Aflatoony
Assistant Professor, School of Industrial Design
Sang Leigh
Assistant Professor, School of Industrial Design



TABLE OF CONTENTS

ABSTRACT

1. INTRODUCTION

- 1.1 Background
- 1.2 Research Problem
- 1.3 Goals
- 1.4 Methodology

2. RESEARCH

- 2.1 Prior Art Review
- 2.2 Survey and Findings
- 2.3 Draw Design Criteria
- 2.4 Topic Narrow Down
- 2.5 Persona & User Journey Map

3. DESIGN

- 3.1 Concepts Ideation
- 3.2 Concepts Evaluation
- 3.3 Selected Concept
- 3.4 Technology Exploration & Concept Refinement
- 3.5 Final Concept
- 3.6 App Design

4. PROTOTYPE

- 4.1 CAD Model
- 4.2 Rendering
- 4.3 Physical Model
- 4.4 Introduction Video

5. EVALUATION

- 5.1 User Test
- 5.2 Expert Review

6. CONCLUSION

- 6.1 Limitations & Potential
- 6.2 Revised Model
- 6.3 Next Step

7. ACKNOWLEDGMENT

APPENDIX

ABSTRACT

Key words:

Road Safety, Hearing Impaired, Cyclists, Haptic Device

The hearing-impaired group is a very important part of our society. According to WHO, over 5% of our populations have disabling hearing loss. To those people who love cycling, the loss of hearing makes them more exposed to unexpected danger.

However, there are few designers notice this growing vulnerable group. It barely has any products on the market designed for improving hearing-impaired cyclists' road safety. And during our research process, I didn't find many projects to investigate these people's needs.

This project is focusing on improving road safety for deaf cyclists. By conducting user research and user-centered design, I draw solid design criteria and designed a haptic wristband with a detachable radar detector to provide rear-end traffic to users. Our project is just a start, I hope it can eventually raise the public's attention to the hearing-impaired group.

INTRODUCTION

1.1 Background

Live in modern life, I have to coexist with vehicles. While people are enjoying the convenience vehicles bring, traveling safely is becoming more and more challenging to pedestrians and cyclists. Only in 2017, 5977 pedestrians and 783 cyclists were killed in traffic fatalities in the US [4], what's more, the numbers are increasing steadily every year.

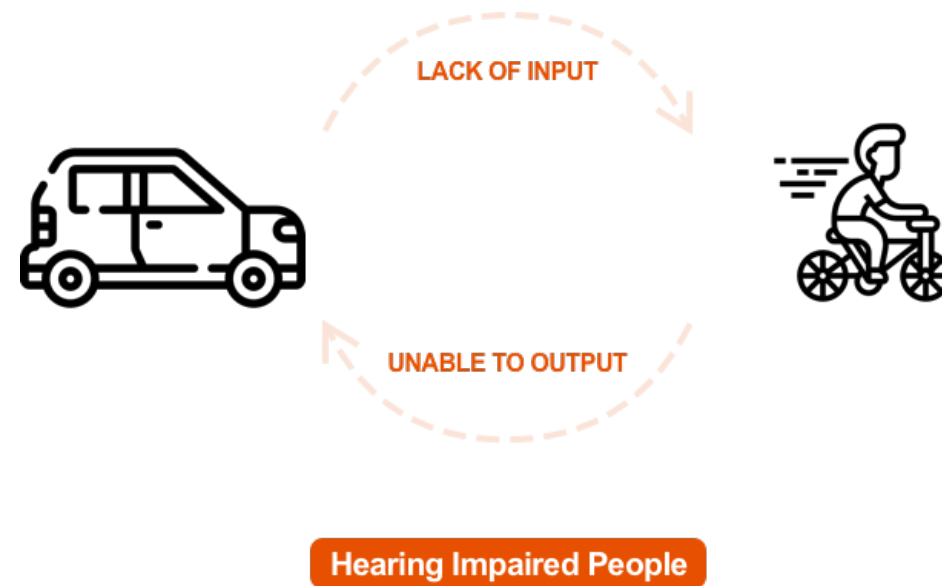
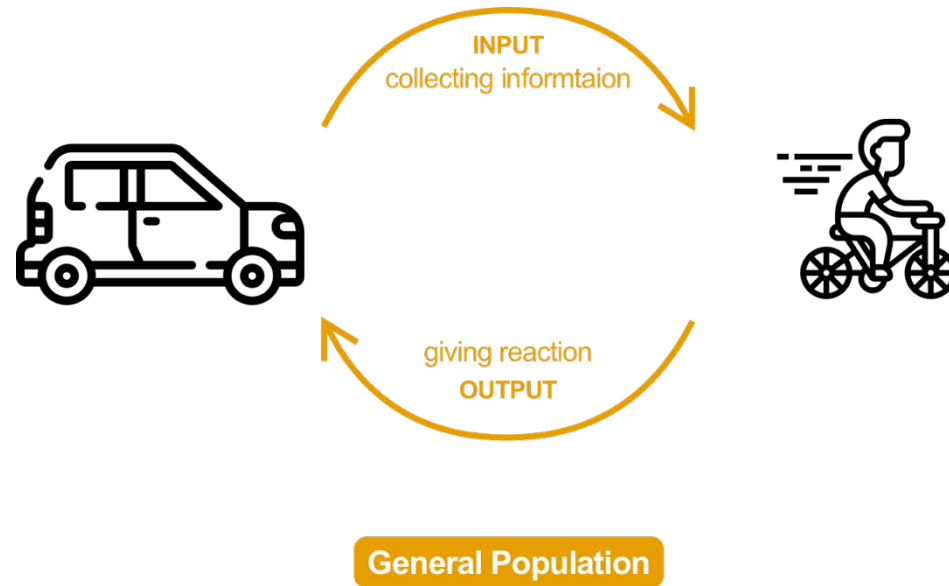
As an important part of pedestrians and cyclists, the hearing-impaired group is also expanding at a high speed. According to the report provided by WHO (World Health Organization), over 5% of the world's population – or 466 million people – has disabling hearing loss, this number will increase to over 900 million by 2050 [9]. How to help this growing vulnerable group travel safely is now a worldwide important problem.

1.2 Research Problem

Compared to general populations, the hearing-impaired group is more likely to face unexpected dangerous traffic situations, since their efficient communication with the outer environment has been ruined. Commonly, the information exchange between pedestrians/cyclists and outer environment contains input and output:

- 1) collecting information (input)
- 2) giving reaction (output)

Due to the hearing loss, people are unable to obtain enough information such as coming traffic, emergency vehicles' horns, shout, audible warnings, strange noise, and audio traffic announcements. Correspondingly, they may react less to traffic and be unaware of or less aware of danger [3]. This makes nearby drivers mad at the hearing-impaired group since they don't know these people have hearing loss, they just assume these people have received the cues [1] without giving any feedback. The contradiction between the outer environment and the hearing-impaired group deteriorates in this dilemma.



Though losing the hearing, pedestrians can look around to remedy the input. Cyclists are facing a tougher situation. Traffic and road conditions ahead have already occupied most of their attention, it's really hard for them to know what's happening behind, especially when wearing the helmet. This sometimes makes them fail to yield and places them in dangerous situations. The failure to yield is an important factor in the fatal motor vehicle-bicycle crash and a common underlying characteristic in the non-fatal collision [4]. Thus, I decided to choose hearing impaired cyclists as our design objective.

“What kind of information do hearing-impaired people need?”

“How can I rebuild the information exchange for hearing impaired cyclists?”

1.3 Goals

This project is focusing on improving road safety for deaf and hearing-impaired cyclists. However, during our research process, I found there are few studies related to designing for hearing impaired people.

Therefore, except for designing a portable device to assist hearing impaired cyclists, from our study and research, I also want to draw solid criteria about designing products for hearing impaired people, not only cyclists but also pedestrians. I hope this project can eventually raise the public's attention to this growing vulnerable group.



Mid-term Goal

Draw solid criterion about designing products for hearing impaired people.



Project Goal

Design a portable device to improve hearing impaired cyclists' road safety.



Long term Goal

Raise the public's attention to the growing hearing-impaired group.

1.4 Methodology

At the earlier stage, I did a prior art review and literature review to find design opportunities. User-centered design (UCD) is also adopted during the research, design, and evaluation process. UCD calls for involving users throughout the design process via a variety of research and design techniques to create highly usable and accessible products for them. [10] This methodology will help us a lot since this project is based on users' real daily issues, the more I understand users the better design criteria I can get.

I utilized questionnaires to collect data and do the online expert review. Asking deaf people questions about their real experiences and thoughts on the design will help us better understand their situation, requirements, and design limitations. More than 30 hearing-impaired people took the questionnaires.

Since the main outcome of this project will be a portable device, it is very important to evaluate and revise the design based on the user test. 7 users were invited to try on the device and accomplish several tasks.

Research



- Prior Art Review
- Literature Review

- Design Questionnaire
- IRB Approval

- Participants Recruitment
- Conduct Online Survey

- Analyze Survey Data
- Conclude Design Criteria



Design



- Find Design Opportunity
- Explore technology

- Concepts Ideation
- Sketch & Storyboard

- Concepts Evaluation
- Choose Final Design

- Build CAD model
- Make Low & High Fidelity Prototypes



Evaluate



- Expert Review

- User Test

- Feedback Collection
- Analyzation

- Refinement
- Conclusion

RESEARCH

2.1 Prior Art Review

2.1.1 Method and Purpose

In prior art review, I looked up products and research projects related to hearing-impaired people's road safety issues.

I wanted to discover the user pain points of these existing products and assess the technologies which have been adopted. By analyzing these designs, I concluded some design insights and found the direction for our next step.

2.1.2 Safe Cycling Riding Helmet



A'DESIGN AWARD
& COMPETITION



<http://www.adesignaward.com>



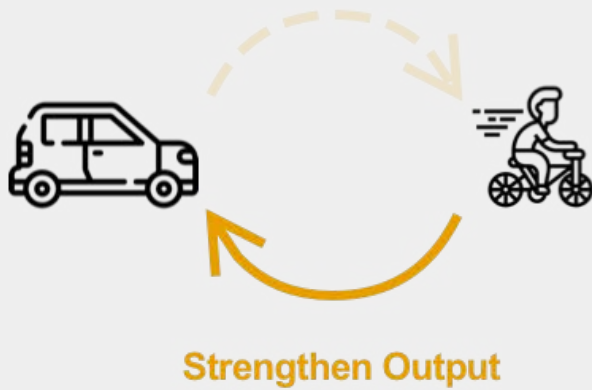
Safety Cycling Riding Helmet

Product designer Ce Zhong and Yvonne Ku have designed a Safety Cycling Riding Helmet which will project the “Deaf Cyclist” sign to the ground behind the cyclist [8].

This design has a highlighted advantage, the helmet eliminates the lack of visibility which is another common factor in motor vehicle-bicycle fatalities, commonly resulting from the bicyclist not being conspicuous to other roadway users due to dark clothing and/or poor or no lighting [4]. However, it just relieves the contradiction between the cyclist and nearby traffic instead of rebuilding the information exchange. The cyclist is still unable to obtain signals from nearby traffic. Another conspicuous vulnerability is the restriction in usage time, the projector can only work well in dark.

What’s more, this helmet project the word “DEAF” on the ground which is straightforwardly telling every passenger the fact that this cyclist is a person with a disability. This might cause mental stress to those people who consider deafness as privacy.

CONTRIBUTION



ANALYZATION

PAIN POINTS



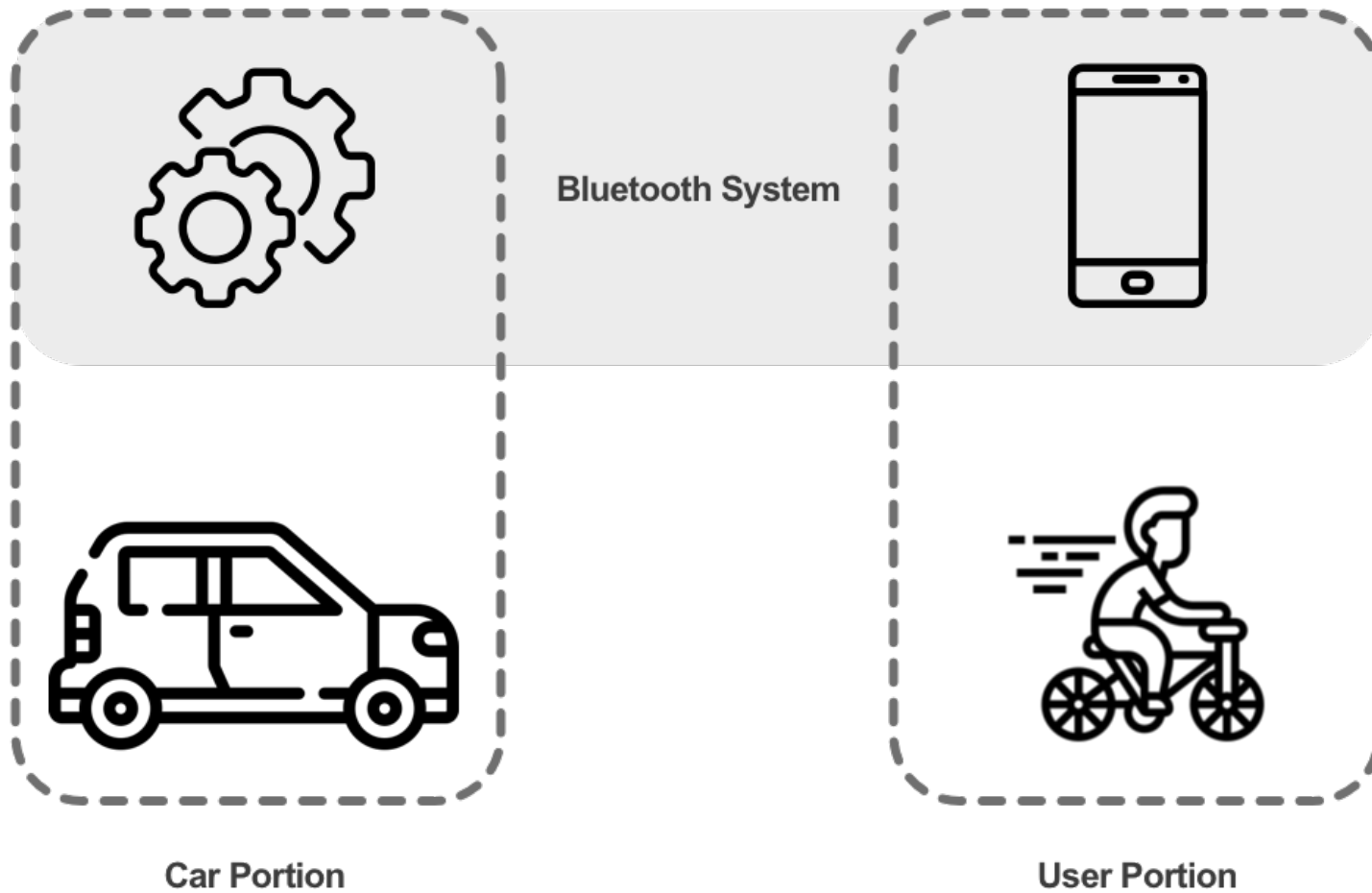
Restricted by time and environment.
Doesn't rebuild the information exchange.
Put users in passive condition.
May cause users' mental stress.

GAIN POINTS



Eliminate users' lack of visibility.
Strengthen users' output information.
Relief the contradiction.

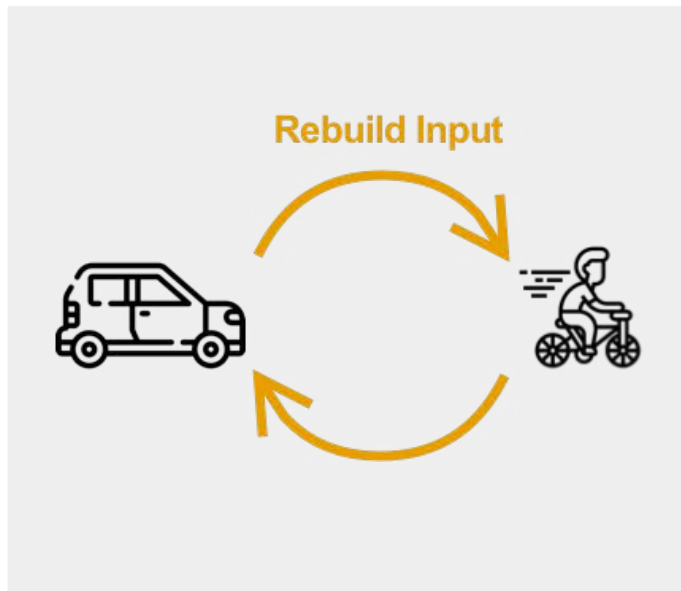
2.1.3 A Portable Bluetooth System



Justin M. Owen from Virginia Commonwealth University raised a design solution from another perspective. His design, a portable Bluetooth system, strengthen the deaf-blind pedestrian's mobility and independence by reporting the coming vehicles [7]. The portable Bluetooth system consisted of the vehicle portion which was put near the car engine and user's cell phone portion. After analyzing the engine sound, the vehicle portion will send the car's speed and direction to the cell phone portion through Bluetooth, the cell phone will use different vibration combinations to inform users.

The starting point of this design is reconstructing the information input, which is good. What's more, this design considered users' loss of hearing and adopted vibrations to express traffic conditions. To hearing-impaired people, haptic is a very efficient way to gain information. However, from the perspective of information exchanging relationships, users are receiving information passively and every vehicle, as the signal generator, has to be manufactured with the Bluetooth device. This is impossible to realize. Another vulnerability is also conspicuous, that the Bluetooth is restricted by distance.

CONTRIBUTION



ANALYZATION

PAIN POINTS



Bluetooth is restricted by distance.
Impossible to add the system to all vehicles.
Users receive information passively.

GAIN POINTS

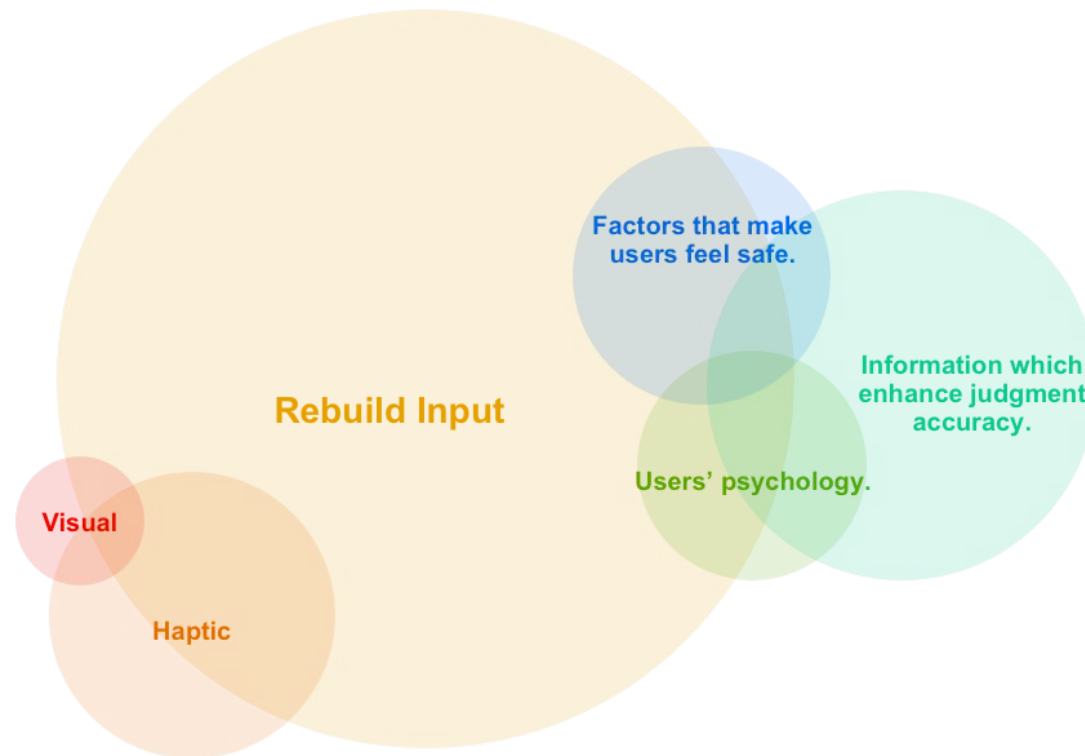


Users can obtain traffic information.
Rebuild the information input.
Haptic information is efficient to deaf people.

2.1.4 Insights

From these two prior arts above, I know that to rebuild the information exchange between the outer environment and the hearing-impaired group, I need to focus on the input method, especially when I am designing for cyclists. Haptic could be a very efficient way to send information to hearing-impaired users. Once receive sufficient information, they can voluntarily give the right feedback. What's more, I need to set people as our design objective to increase the feasibility.

To make a better design, I can also find design opportunities in 1) factors that make deaf pedestrians and cyclists feel safe, 2) information which will enhance their judgments' accuracy on busy streets, and 3) their psychology when facing unexpected traffic situations.



2.2 Survey and Findings

2.2.1 Method and Purpose

From prior art review, I knew that the best way to rebuild information exchange is rebuilding their information input. But what kind of information is most needed by users? What are the factors that make them feel safe? How do they feel when cycling or walking on the busy street?

To better understand our users, I conducted this survey. A questionnaire with 6 questions was designed and 18 participants were recruited.

2.2.2 IRB Review

Since I am going to recruit hearing-impaired people to participate in this project, to protect their rights, I submitted this IRB protocol.

Protocol H19245 -- Improving Road Safety of Pedestrians and Cyclists with Hearing Loss

Approved on Sep. 17th, 2019

The screenshot displays the IRBWISE web application interface. At the top, there is a search bar for "Search by Protocol Number:" and a "Go" button. To the right, there are links for "HOME", "PASSWORD", and "LOGOUT". Below the search bar, a progress bar shows the workflow: "Summary of Protocol H19245" (selected), "With PI", "With Department Head Approval", "Submitted to IRB", "Under Review", and "Final Disposition". A "Welcome to IRBWISE, Siran Liao." message is on the right. Below the progress bar, there are tabs for "submission", "permissions", and "history". The "summary" tab is active, showing details for Protocol H19245. The title is "Improving Road Safety of Pedestrians and Cyclists with Hearing Loss". The Principal Investigator is Jon Allen Sanford, and the Admin Assigned is Steven Joseph Anzalone. The Committee Assigned is Central Institutional Review Board #1, and the Review Type is Exempt Review. The Current Status is Approved, Last Activity is 03/12/2020 - Amendment for H19245 Forwarded to PI, Original Approval Start is 09/17/2019, and Current Approval Period is 09/17/2019 - Indefinite. Below this, there is a "Protocol Summary" section with a "print" button. The summary table lists the Protocol Description, Protocol Department (CATEA), Research Personnel (2 personnel), Researcher Certifications (listing various CITI and training certifications), Amendments (1 Amendment request created, 0 approved), and Continuing Reviews (none).

Protocol H19245	
Title: Improving Road Safety of Pedestrians and Cyclists with Hearing Loss	
Principal Investigator: Jon Allen Sanford	
Admin Assigned: Steven Joseph Anzalone	
Committee Assigned: Central Institutional Review Board #1	
Review Type: Exempt Review	
Current Status: Approved	
Last Activity: 03/12/2020 - Amendment for H19245 Forwarded to PI	
Original Approval Start: 09/17/2019	
Current Approval Period: 09/17/2019 - Indefinite	

Protocol Summary	
Protocol Description:	Pedestrians and cyclists with hearing impairments are vulnerable in the bustling traffic we have nowadays. Due to the hearing loss, they cannot receive sufficient safety cues from the outer environment, thus, they have to always keep their eyes on the passing vehicles. This project investigated the road safety issues of pedestrians and cyclists with hearing impairments. We will use Qualtrics to conduct an online survey with 25-200 participants to better understand the common issues and information which will improve their safety.
Protocol Department:	CATEA
Research Personnel:	2 personnel
Researcher Certifications:	certification details 1 researcher has active "CITI: IRB Health Information Privacy and Security (HIPS)" certification 1 researcher has active "Department of Navy (DoN) CITI Training Certificate" certification 1 researcher has active "Air Force Research Laboratory (AFRL) CITI BASIC Training Certificate" certification 1 researcher has active "Georgia Tech CITI Human Subjects Training Certification" certification 1 researcher has active "CITI: IRB Refresher IRB Members" certification 1 researcher has active "Other Institution IRB CITI Training" certification 1 researcher has active "CITI: IRB Biomedical Training" certification 1 researcher has active "CITI: Good Clinical Practice Biomedical" certification
Amendments:	1 Amendment request created , 0 approved
Continuing Reviews:	none

2.2.3 Participants Recruitment Plan

All the participants must be people who have different degrees of hearing impairment and must age 18 or above. People who cannot make decisions independently will not be involved in this study. People located in the European Union countries are not allowed to take this survey.

Due to the infrequency of the target user segment, I decide to obtain approximately 20 answers in this survey. I invited a research scientist from TechSAge to help us spread the flyer to 50 people in the registry who 1) reported difficulty hearing when signing up for the registry and 2) have an email. I also got a person from the deaf community to spread the flyer with her contacts. Furthermore, I post a notice at Yahoo group “Epeachy listserv” which is a listserv for the deaf community. If people decide to be in this study, they can click the link on the flyer to read the consent. On the consent page, they will be asked to click on the checkbox at the end of this page and submit the consent. They will be automatically directed to the online questionnaire. Finally, I received 18 answers.

View the full consent in the appendix.



People with Hearing Impairment are Needed to Complete an Online Survey about The Road Safety Issue

In order to improve the road safety of people with hearing impairment, researchers are conducting a survey to better understand their daily challenges. This is an anonymous online survey. It will only take approximately 10 minutes to complete, but it is an important step in improving the overall travel safety of the deaf community.

Participants in this study must be people who have different degrees of hearing impairment and must age 18 or above. People who cannot make decisions independently will not be involved in this study.
If you are located in a European Union (EU) country, you are not permitted to participate in this study due to the General Protection Data Regulation (GDPR).

You can click on the link below to access the consent.
By reading and submitting the consent, you will be automatically redirected to the online survey:
https://gatech.co1.qualtrics.com/jfe/form/SV_00K91LutonT6m2x

For more information, please contact:

Siran Liao
Email: siranliao@gatech.edu
Phone: (404)-547-9146

Help Us Create Safety !



Recruit Flyer

2.2.4 Questionnaire Design

This questionnaire contains 6 questions which can be divided into 4 sections based on their purposes.

- 1) To know the participants' age group.
- 2) To understand what factors make them feel safe while walking/cycling on a busy street.
- 3) To investigate the information needed most while walking/cycling on a busy street.
- 4) To know how they currently monitor the rear-end traffic.

The link to the online consent and questionnaire:

https://gatech.co1.qualtrics.com/jfe/form/SV_0OK91LutonT6m2x

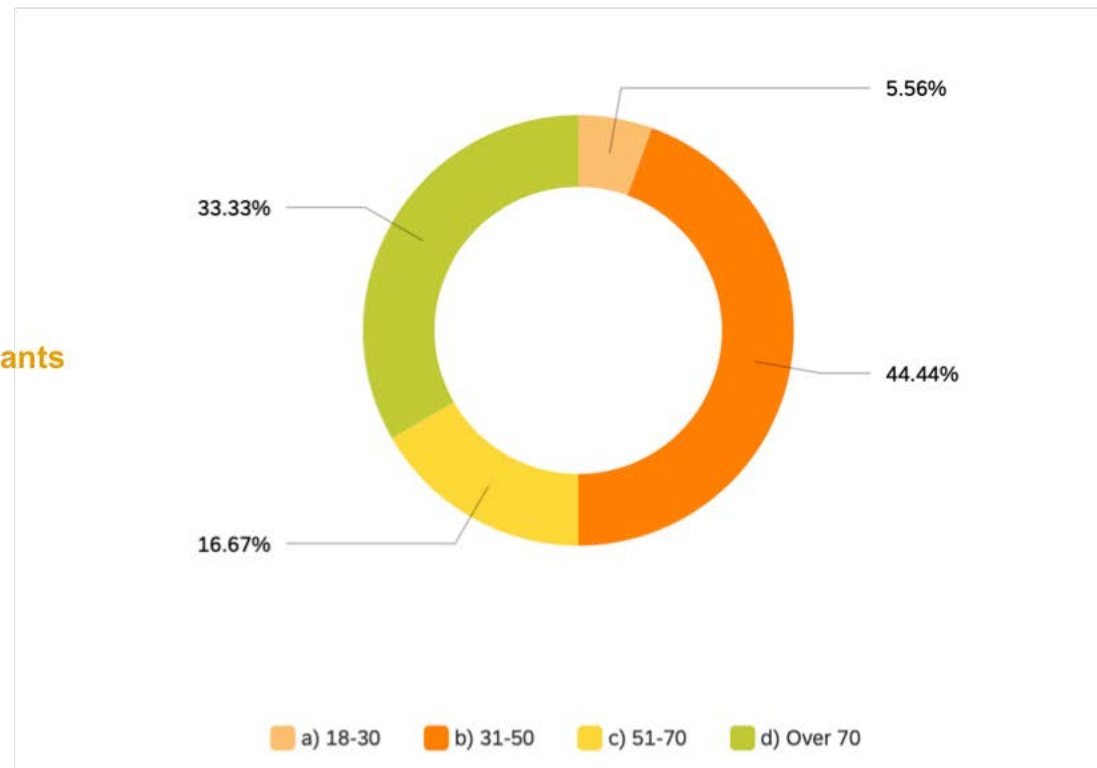
Or view the full questionnaire in the appendix.

2.2.5 Data Analysis

1. Overview and age group.

Among these 18 hearing-impaired participants, 8 of them came from group b (31-50), 6 aged over 70, 3 came from group c (51-70), and only 1 participant came from the group a (18-30).

18
Hearing-Impaired Participants



2. Factors that make them feel safe when crossing a busy street.

I ask them to rate how safe they feel when crossing a busy street at a four-way intersection with different facilities. This question helps us to know what kind of traffic facility will provide deaf pedestrians more sense of security. The result is: stop sign > stop light > crosswalk > no traffic signals or crosswalks.

Crossing a busy street at a four-way intersection with no traffic signals or crosswalks.



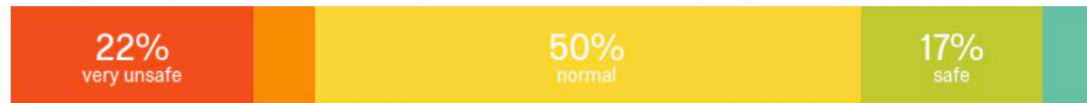
Crossing a busy street at a four-way intersection with crosswalks only.



Crossing a busy street at a four-way intersection with stop lights only.



Crossing a busy street at a four-way intersection with stop signs only.



very unsafe unsafe normal safe very safe

3. Factors that make them feel safe when cycling on a busy street.

I ask them to rate how safe they feel when cycling on a busy street with different facilities. This question shows us what kind of traffic facility will provide deaf cyclists more sense of security. The result is: bike lanes with physical barriers > shared lanes > bike lanes with no physical barriers > no bike lane.

Riding a bicycle on a busy street with no bike lanes.



Riding a bicycle on a busy street with bike lanes that do not have barriers.



Riding a bicycle on a busy street with sharrows (shared lanes) only.



Riding a bicycle on a busy street with bike lanes with physical barriers.



very unsafe unsafe normal safe very safe

4. Most needed information when crossing a busy street.

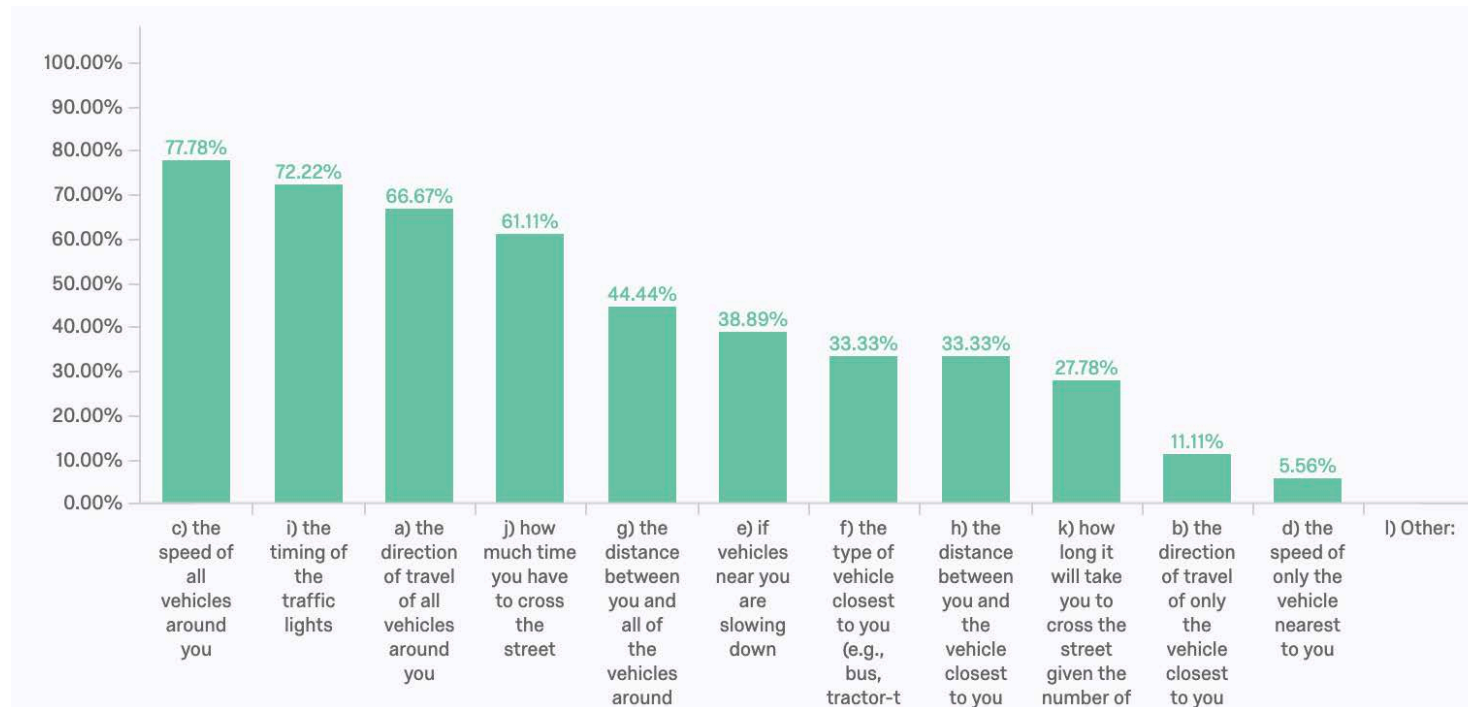
I ask them to choose the information they want to obtain when crossing a busy street. Based on the result, I consider information category c, i, a, j as the most important information for deaf pedestrians to safely cross the busy street since more than 50% of participants choose them.

c) the speed of all vehicles around you. 77.78% (14/18)

i) the timing of the traffic lights. 72.22% (13/18)

a) the direction of all vehicles around you. 66.67% (12/18)

j) how much time you have to cross the street. 61.11% (11/18)



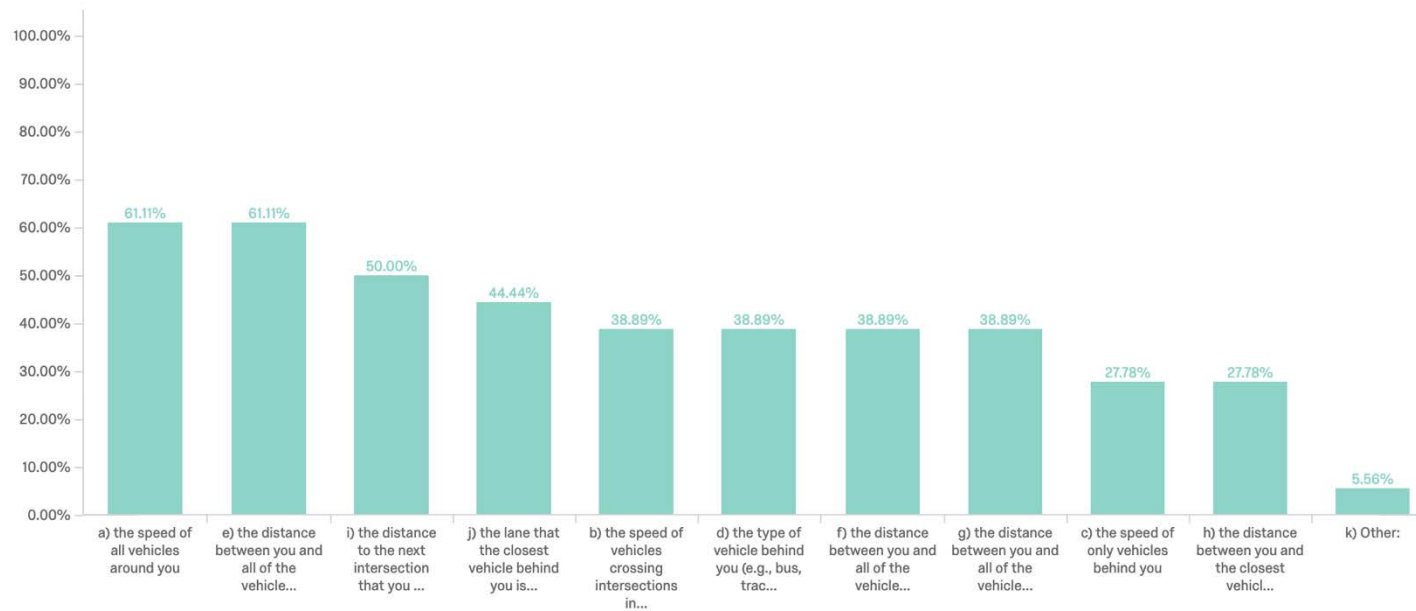
5. Most needed information when cycling on a busy street.

I ask them to choose the information they want to obtain when cycling on a busy street. Based on the result (Pic. 9), I consider the information category a, e, i as the most important information for deaf pedestrians to safely cross the busy street since more than 50% of participants choose them. However, I think category j, b, and d also have a high reference value.

a) the speed of all vehicles around you. 61.11% (11/18)

e) the distance between you and all of the vehicles around you. 61.11% (11/18)

i) the distance to the next intersection that you will ride across. 50.00% (9/18)



6. Tools they currently adopt to monitor the rear-end traffic.

In the last question, I asked whether they use any tools to monitor the traffic behind. 13 people say No, and the mirror is the only tool for those 5 people who choose Yes.



13

Participants have NO TOOLS



5

Participants use MIRROR

2.3 General Design Criteria

2.3.1 Method and Purpose

As mentioned before, except designing a portable device for hearing-impaired cyclists, our mid-term goal is to draw solid design criteria from our research. I hope these design criteria can be shared with other designers when they are dealing with similar topics.



2.3.2 Design Criteria of Input Information

The criteria draw from question 2 & 4:

- The design needs to collect the speed of vehicles around the user.
- The design needs to know the directions of nearby vehicles.
- The design needs to collect the information of traffic lights when design for pedestrians only.

The criteria draw from question 3 & 5:

- The design needs to calculate the distance between nearby vehicles and the user.
- The design needs obtain the accurate location of the user.
- The design needs to obtain the navigation information to better fulfill the function.

2.3.3 Design Criteria of Output Information

The criteria draw from question 2 & 4:

- The design needs to show the speed of vehicles around.
- The design needs to show the directions of nearby vehicles.
- It's better to provide some suggestions about crossing the road when design for pedestrians only.

The criteria draw from question 3 & 5:

- The design needs to show the distance between the user and nearby vehicles or give some alerts when the vehicles are close.
- The design needs to have computing power to turn raw data into useful information.
- Haptic and visual are the best way to express information.
- When present visual information to cyclists, it's better to put the information in eye level.
- It's better to let cyclists know the types of nearby vehicles.

The criteria draw from question 6:

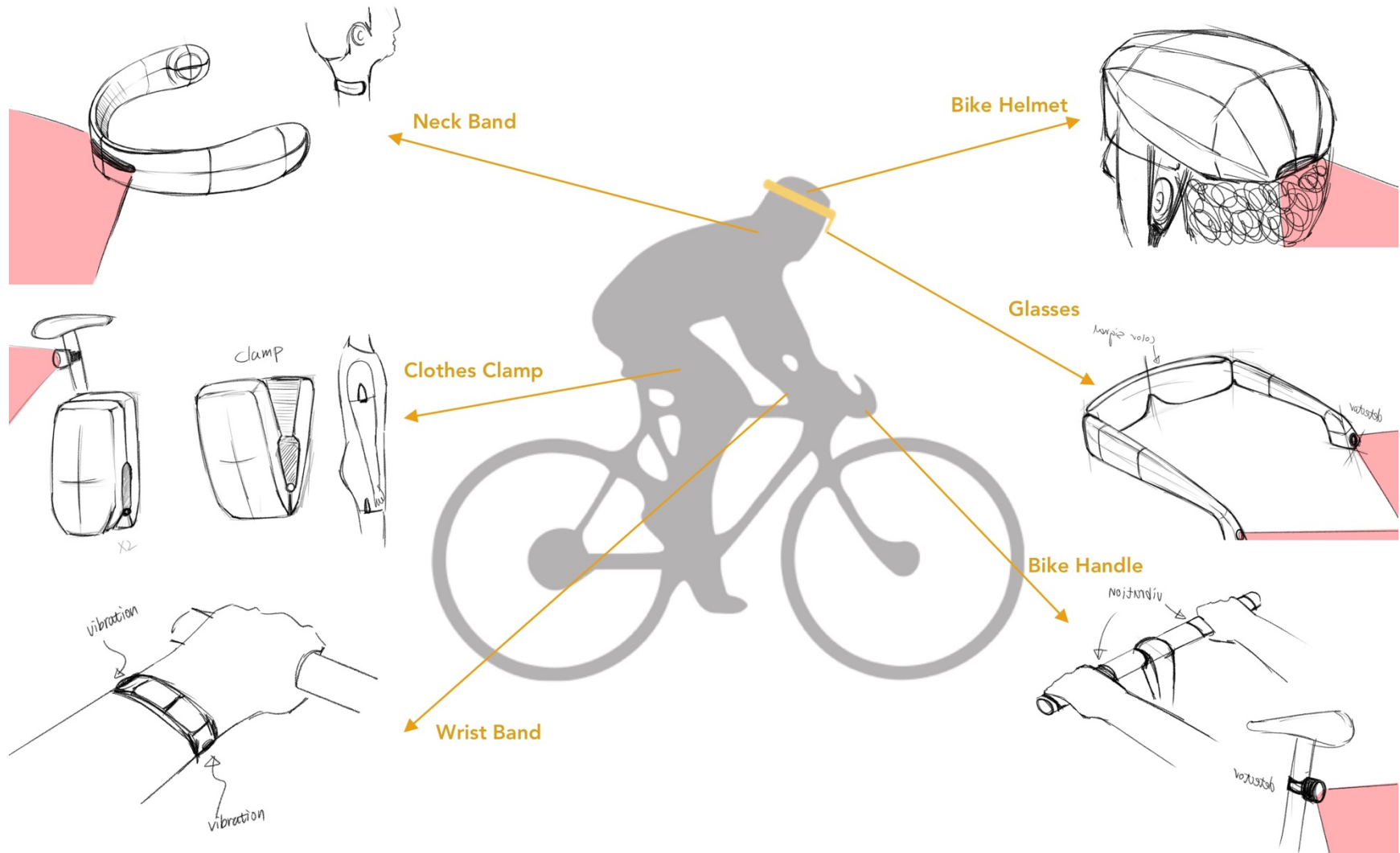
- The design needs to be light and small when it is wearable or portable.
- The design shouldn't scatter much attention of the user.

2.4 Topic Narrow Down

2.4.1 Literature Review

Now I have the criteria for designing for hearing-impaired people, especially for our design objective 'cyclists'. There are too many types of information I can provide to cyclists, but I cannot fulfill all at one time with one device. Cyclists are different from pedestrians, riding a bike on the busy street means they have to deal with the complicated traffic condition and unexpected dangerous incidents. To hearing-impaired cyclists, haptic information might be safer and more efficient than visual information. Later, some cyclists substantiated this idea.

After discussing with my director, I determined to design a haptic wearable device with a traffic detector. But here came the questions, where to wear? A wearable device means it could be a headband, a necklace, clothes, a glove, or a wristband.

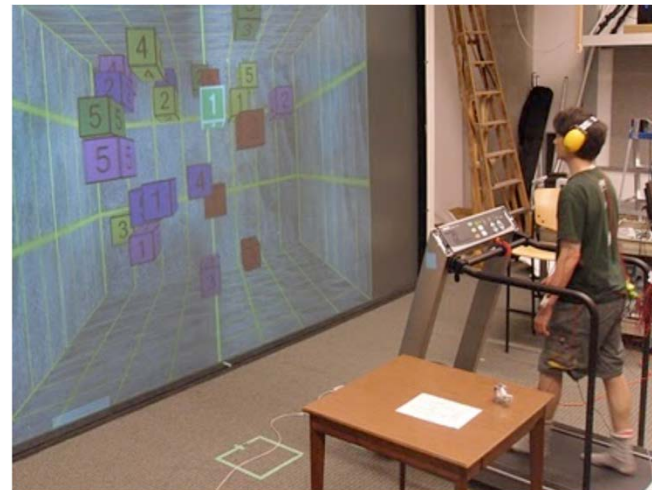
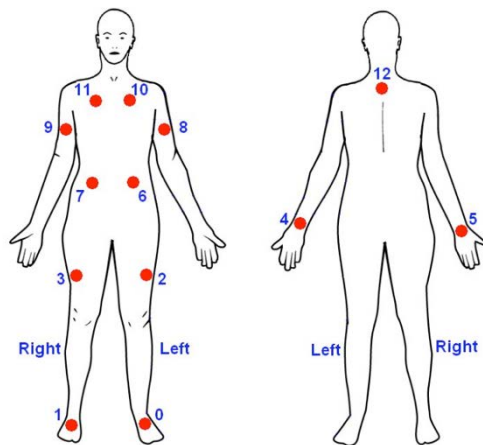


Based on my ideation, I planned to recruit 12 Participants, ask them to ride a spinning bike while watching a video, and put stimuli on both sides of their palm, wrist, arm, neck, and head. This would help me find out the most suitable body spot for wearing this haptic device and investigate the proper vibration intensity range.

But soon, the Covid-19 pandemic started... I was unable to continue this user test.

After doing the literature review, I found investigators from the University of British Columbia have done a research project which focused on finding the best body spot to feel vibrations.

Researchers explored the potential and limitations of vibrotactile displays in practical wearable applications, by comparing users' detection rate and response time to stimuli applied across the body in varied conditions. [12] In one of their tests, 16 participants (8 males) were asked to walk on a treadmill during the test to simulate the daily movement. To simulate the visual interference, investigators placed a TV in front of the treadmill, participants were asked to count the boxes shown on the screen. Vibration stimuli were displayed on participants' spine, chest (left & right), upper arm (left & right), wrist (left & right), stomach (left & right), thigh (left & right), and foot (left & right). The test results showed that among all these body spots, the wrist is most sensitive to feel the vibrations.



2.4.2 Draw Design Criteria

Now I can extract a more concrete design criteria for this project.

WHAT

INPUT



Detector

OUTPUT



Wristband

INPUT

It should at least be able to detect the distance between user and the approaching vehicle.

It should be able to the direction of the approaching vehicle.

It could be assembled to bike or be wearable.

It should be able to transmit information to the output portion.

OUTPUT

It should primarily adopt vibrations as the media to express information.

It should be light-weighted and easy to wear.

It should be able to express the direction of the approaching vehicle.

It should be able to express the distance between the user and the approaching vehicle.

2.5 Persona & User Journey Map

2.5.1 Persona

Based on our user research, I created this persona for our project.



JESSICA

Hearing Impaired | Age 44 | Atlanta, GA

Facts about Jessica:

1. Jessica always go cycling with her husband at weekends.
2. Jessica almost lost 60% of her hearing ability.
3. Jessica doesn't wear hearing-aid while cycling, since she has to wear a tight helmet.

Frustrations:

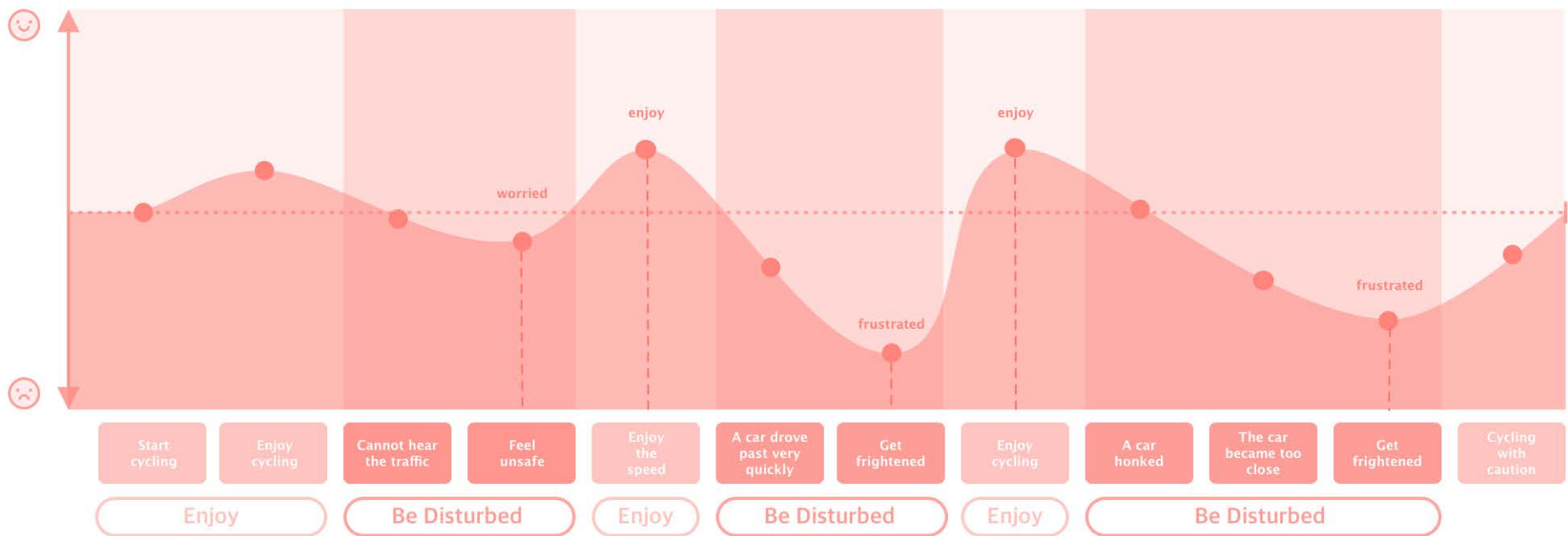
1. Sometimes Jessica adopts mirrors to monitor the traffic behind. But she finds the mirror distract her attentions.
2. Jessica feels very unsafe while cycling since she cannot hear the traffic sound clearly.

Needed Traffic Information:

The distance between she and the vehicle. > The direction of that coming vehicle. > The speed of that coming vehicle.

2.5.2 User Journey Map

I could create a user journey based on our previous research and our persona. Cycling supposed to be a very relaxing outdoor activity, however, the loss of hearing brings some hidden troubles to the cyclists. Even they don't meet any unexpected incidents and inconsiderate drivers, they cannot fully devote themselves to cycling without any concern.



DESIGN

3.1 Concept Ideation

3.1.1 Method and Purpose

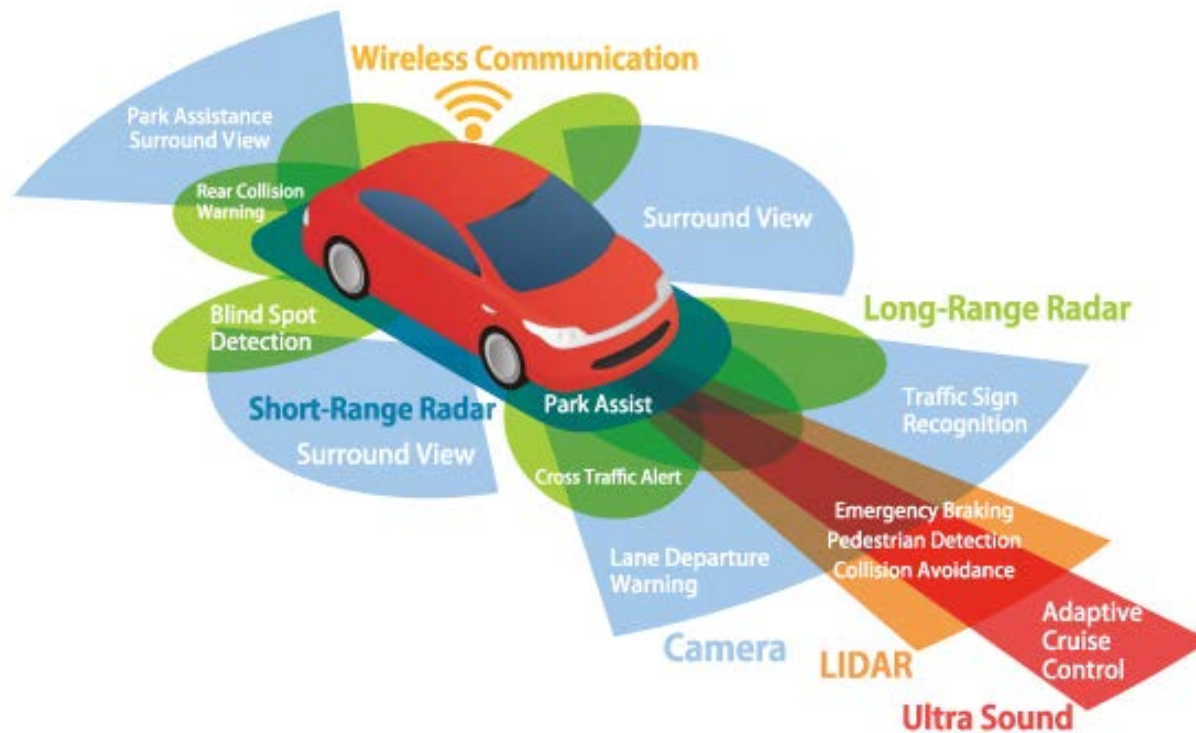
After the research progress, I had the rudiment of what I am going to design. But I still need to enrich our primary idea and make it more specific.

Our ideation process followed a progressive logic, I first found the proper technology for the input method, then ideated the output method, and last but not least, I explored how this product would look like.






3.1.2 Input Technology

Since the input method is going to detect the traffic, I put my eyes on a trending topic: the self-driving industry.

To provide a 360-degree detection, engineers equipped these vehicles with a wide range of technologies like radar, cameras, ultrasound, and radio antennas. These technologies are used in conjunction with one another, as each one provides a layer of autonomy that helps make the entire system more reliable and robust. [13]



As an assistive device to cyclists, it's unnecessary to put all these technologies in our device. A comparison between Camera, Radar, and Lidar technology was made. Using a camera to detect distance might be inaccurate. Lidar can provide full-degree detection, however, the size of lidar is too large to be portable. Considering our actual needs, I picked Radar.

	 Camera	 Radar	 Lidar
ADVANTAGES 	<p>By analyzing video, we can get more information about the approaching vehicles like type and model.</p> <p>We have already have some camera device on the market like GoPro.</p> <p>GoPro can transmit realtime video to users' mobile phone.</p>	<p>The detection of distance is precise.</p> <p>The size could be very small.</p> <p>The information transmission could be real-time.</p> <p>Based on the type, the detect range may vary from several meters to more than 100 meters.</p>	<p>The detection could be three dementional, and more information can be captured..</p> <p>The information transmission could be real-time.</p> <p>The detect angle could be 360-degree.</p>
DISADVANTAGES 	<p>The GoPro app has few seconds delay in real-time video transmission.</p> <p>Calculating distance by analyzing video might be inaccurate.</p>	<p>The detect angle is limited.</p> <p>It can only detect limited information like speed, direction and distance.</p>	<p>The size of lidar element is much bigger than radar and camera.</p> <p>The weight of lidar element is heavier than radar and camera.</p>

3.1.3 Output Method

Indeed, a pair of wristbands (one on the left wrist, another on the right wrist) can better tell the direction. It also means users need to take three individual devices (two wristbands and radar) and charge them separately. Users might also need to distinguish which wristband is for left and which one is for right. Using single wristband will take users some time to get familiar with the vibrations. However, once they go through the orientation, it will be very easy for them to distinguish the directions.

If I'm going to show directions with a single wristband, it must have two separate haptic engines. To make sure users can feel two different vibrations at the same time, there must be enough distance between these two haptic engines.

	 <p>Two Wristbands + Single Radar</p>	 <p>Single Wristband + Single Radar</p>	 <p>Single Wristband + Detachable Radar</p>
ADVANTAGES 	<p>It's easier for users to tell the direction of the approaching vehicle with two wristbands.</p>	<p>More portable than two wristbands,</p> <p>As long as there is enough space between two haptic engines, users will be able to distinguish them.</p>	<p>More portable than two wristbands,</p> <p>As long as there is enough space between two haptic engines, users will be able to distinguish them.</p> <p>Users only have to charge one device.</p>
DISADVANTAGES 	<p>Users have to take 3 devices before cycling and they have to charge three devices.</p> <p>Users have to figure out which one is left and which one is right.</p>	<p>Since the radar and the wristband are two separate devices. Users need to take two devices and charge them separately.</p> <p>Users might need some time to get familiar with the vibrations.</p>	<p>Users might need some time to get familiar with the vibrations.</p>

I have decided to adopt vibrations as the output method, but how can I design the pattern to show distance and directions?

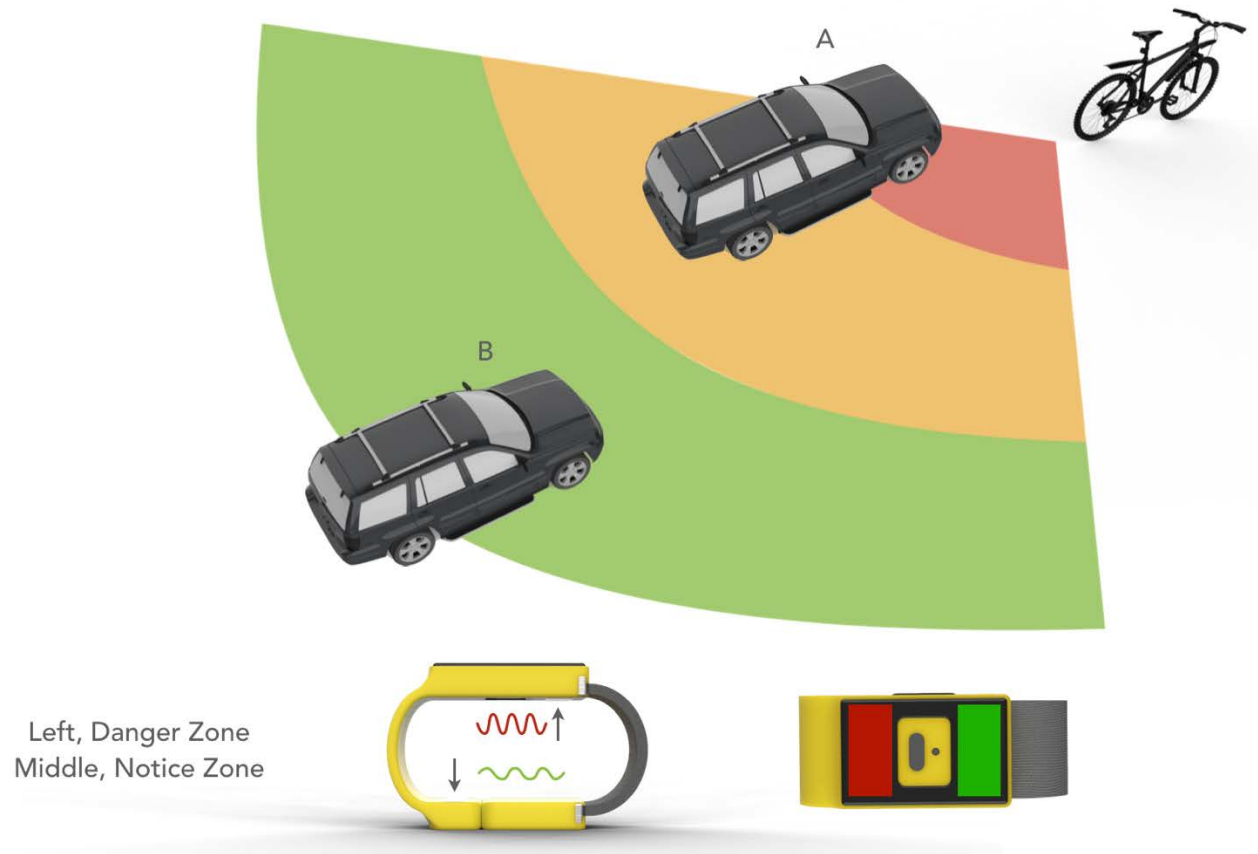
In the beginning, I planned to use different vibration patterns to represent the direction, and change intensity based on the distance. However, I realized this may create too many combinations and be confusing.

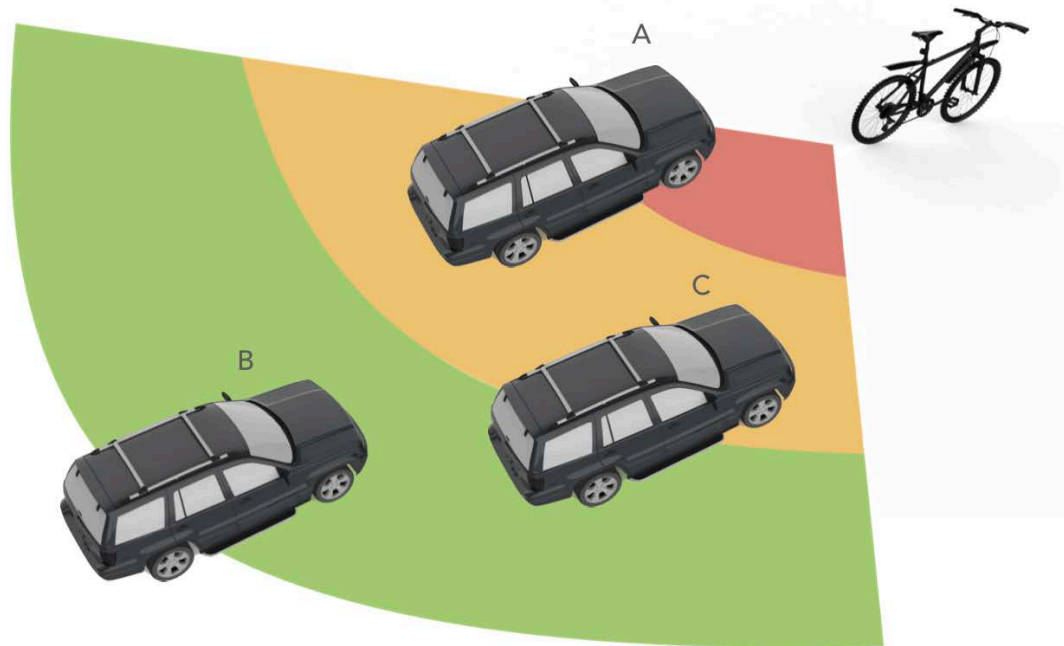
So firstly, I divided the detection area into the left and right two sections. The radar will detect all the vehicles in the detect area, and the wristband will report the closest one in each section. Secondly, to help users position the vehicle precisely, I divided the detect area into three different zones based on the distance: Danger Zone, Attention Zone, and Notice Zone. Each distance will have a specific vibration pattern. Furthermore, I add visual cues to assist information expression. Red represents Danger, orange represents Attention, and the green represents Notice. This color scheme meets the users' understanding of danger.



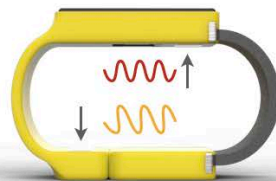
Commonly, the car in the left / right section will be reported by wristband on the left / right side, and the car in the middle will be reported by both sides. No matter how complicated the traffic is, the wristband will simplify it and report the closest vehicles.

Below are two examples.



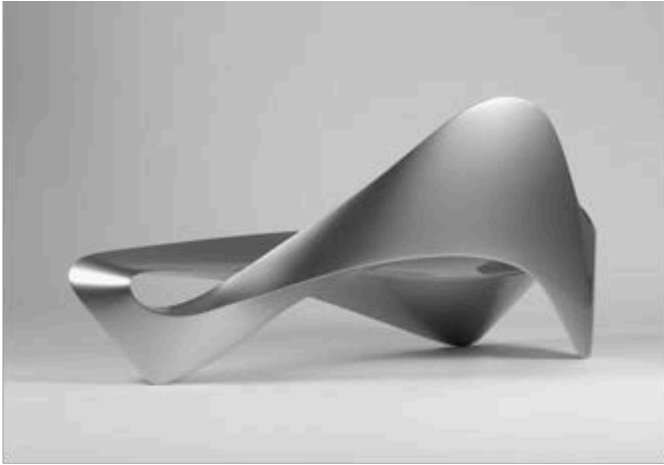


Left, Danger Zone
 Right, Attention Zone
 Middle, Notice Zone

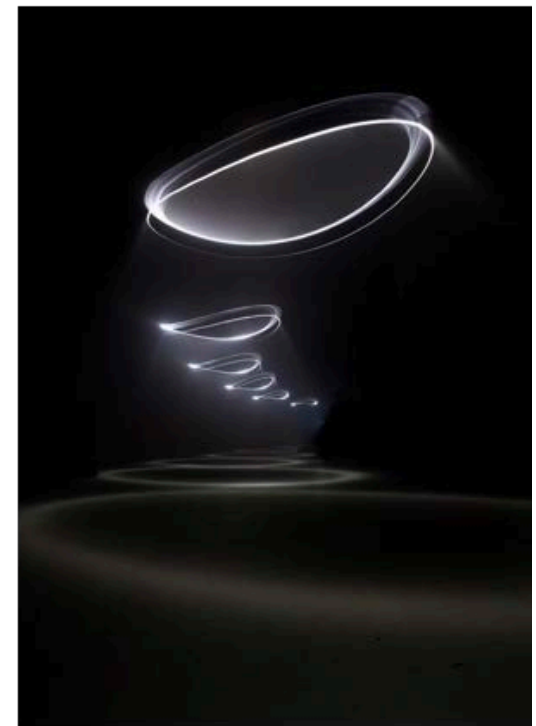
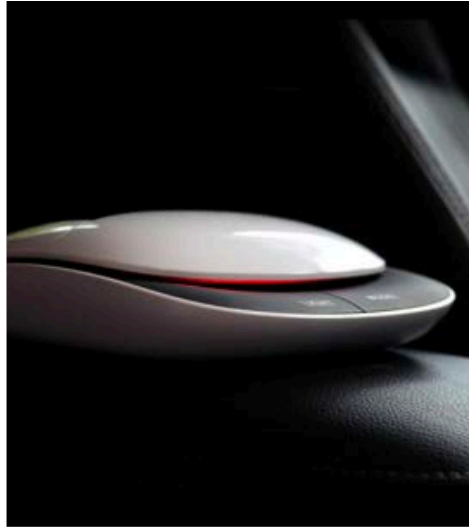


3.1.4 Mood Board

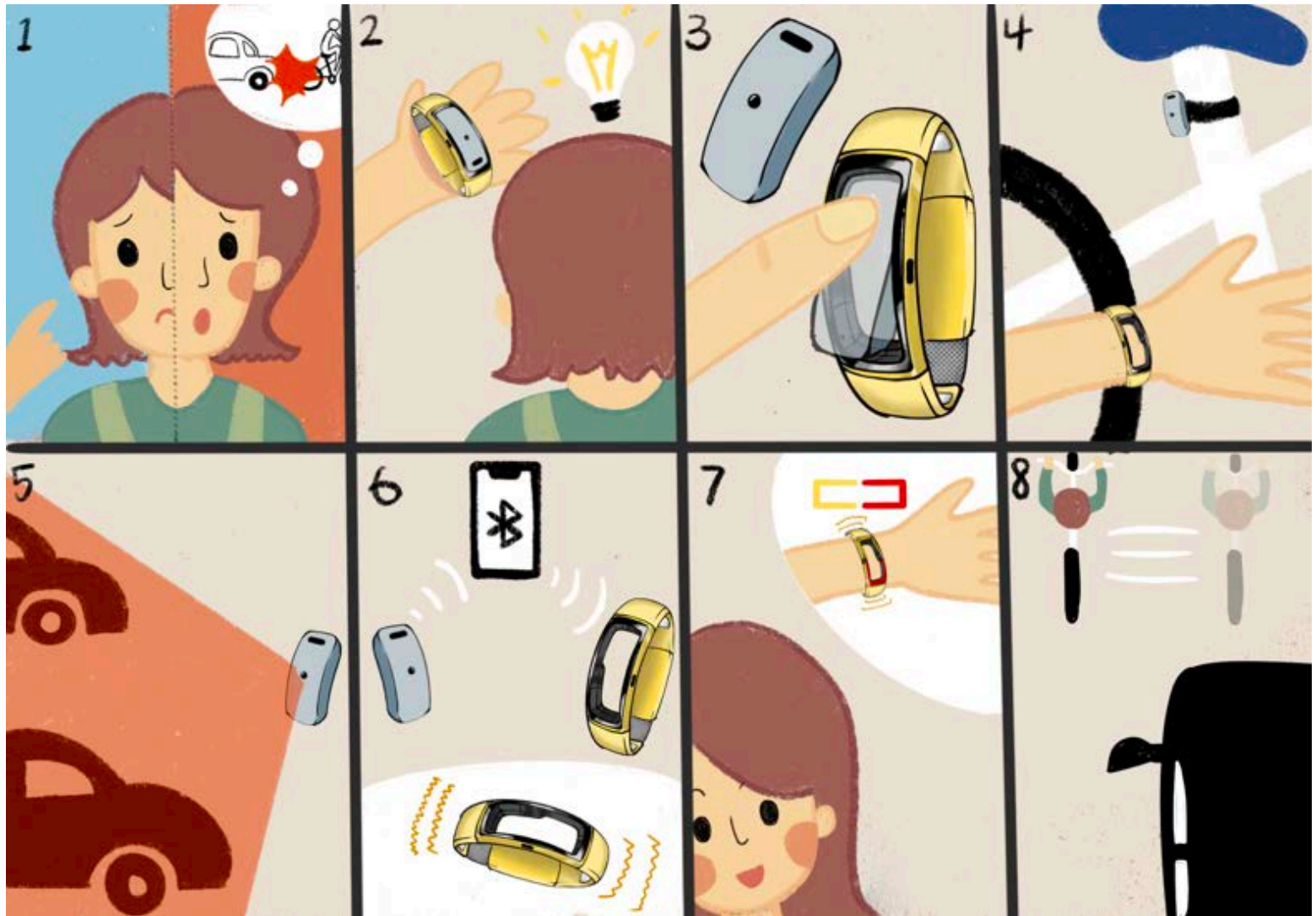
Streamline



Futuristic



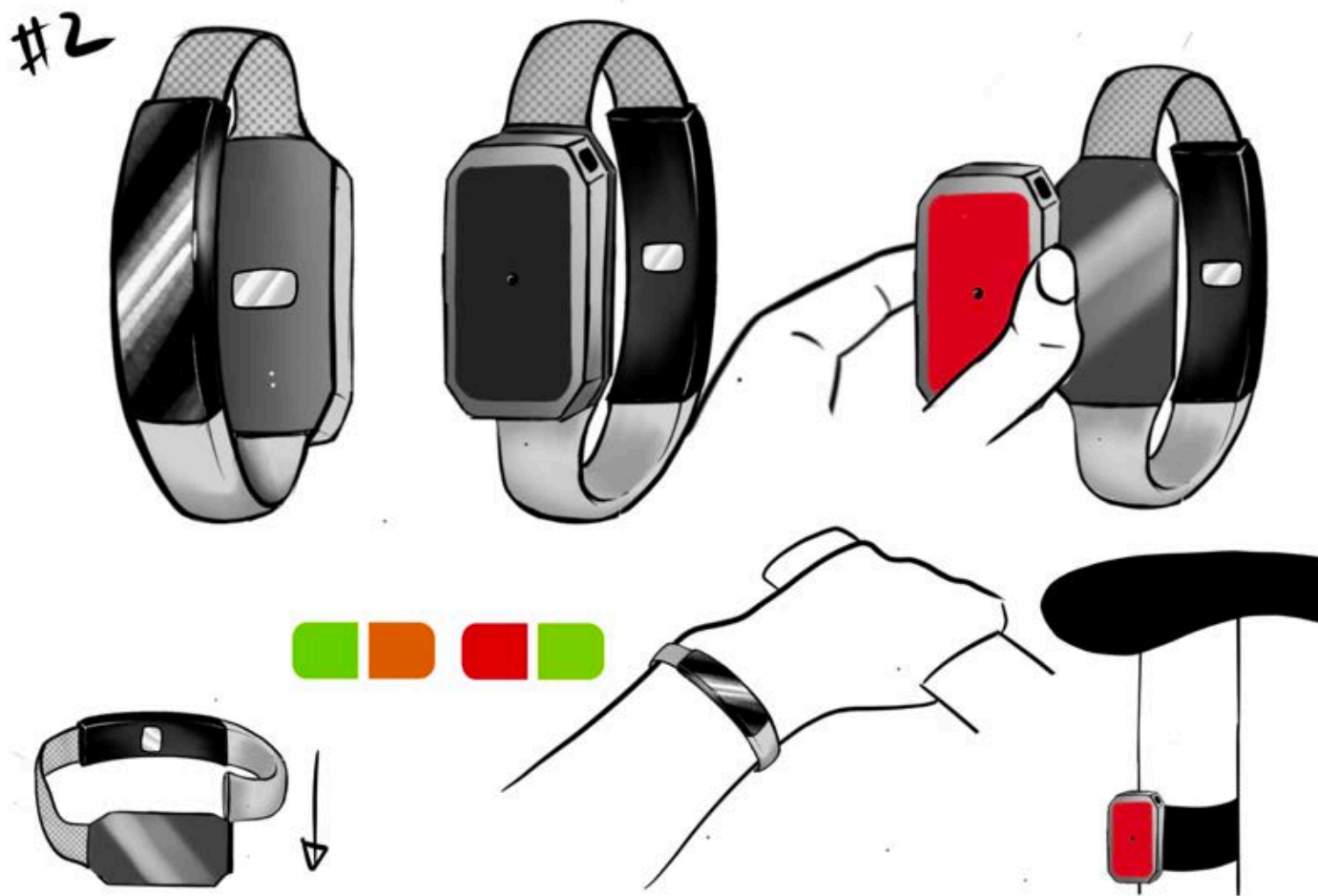
3.1.5 Storyboard



3.1.7 Refined Sketches

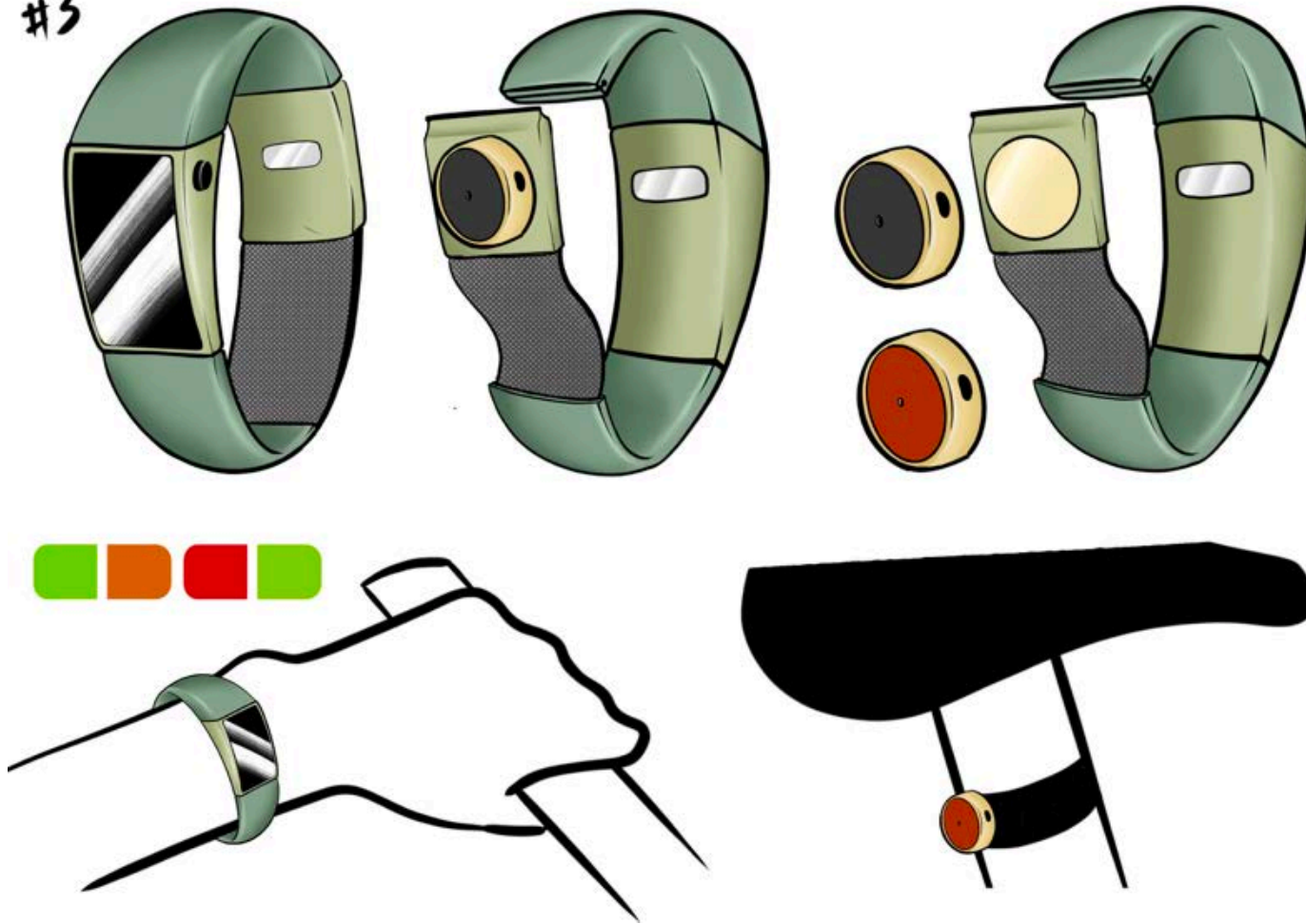


- Radar: inside the wristband.
- Haptic engine: touching users' left & right side.



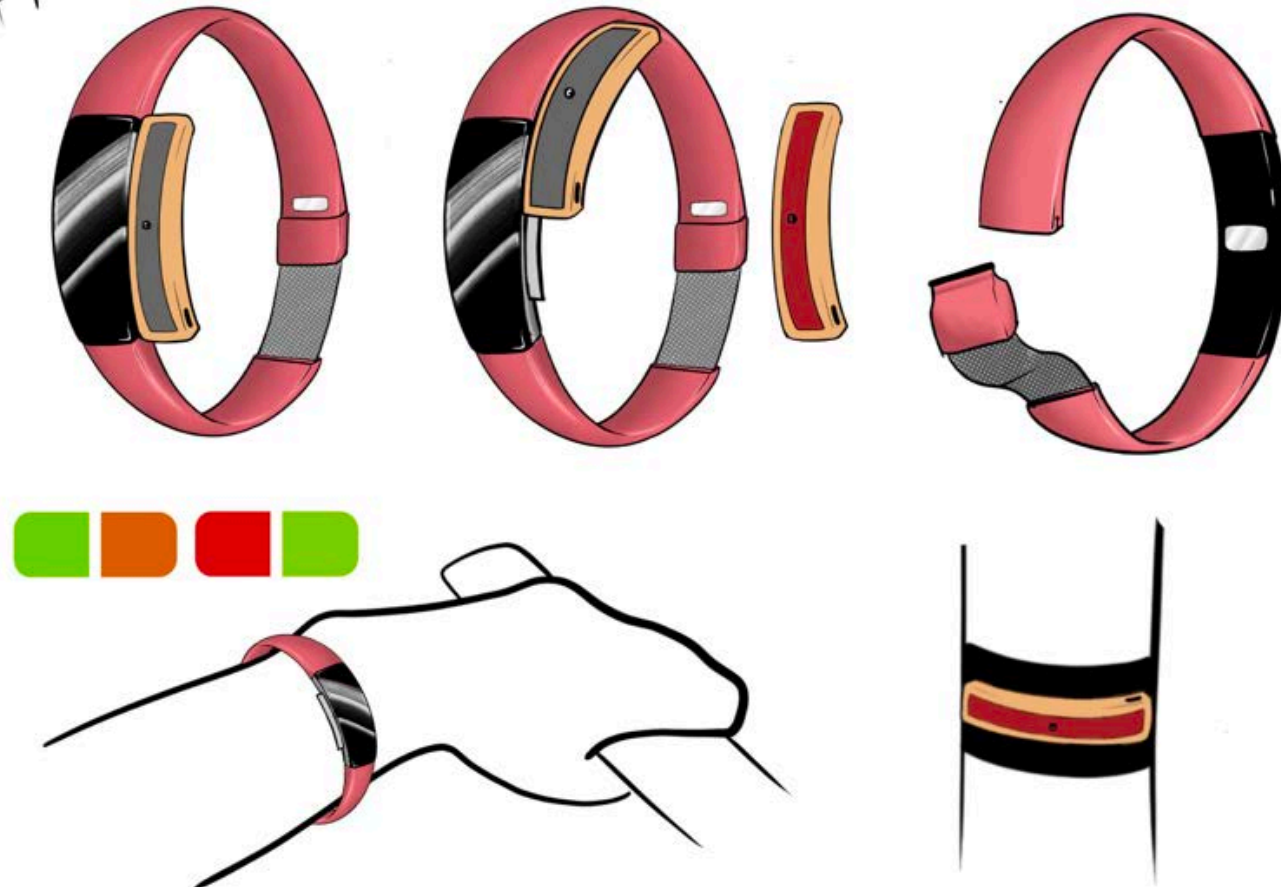
- Radar: on the wristband surface.
- Haptic engine: touching users' upper & lower side.
- Radar could work as a taillight.

#3



- Radar: on the wristband surface.
- Haptic engine: touching users' upper & lower side.
- Radar could work as a taillight. Wristband screen has a slope that could reduce the reflection of daylight.

#4



- Radar: on the wristband surface.
- Haptic engine: touching users' upper & lower side.

3.2 Concept Evaluation

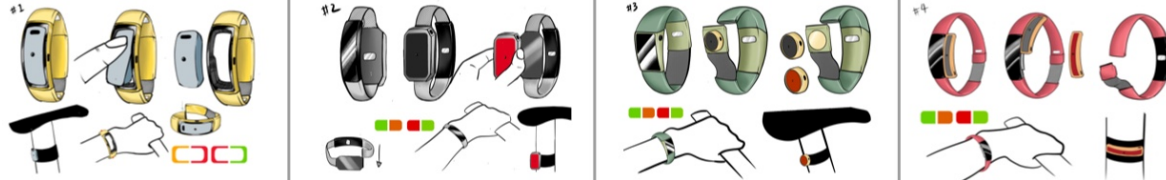
3.2.1 Method and Purpose

I invited four of my design classmates who have cycling experience to help me review these concepts and ask them to rate each concept on a scale from 1 to 5. (1 = very unsatisfied, 5 = very satisfied) Based on their feedback, I conducted the concept evaluation and picked our final direction.

3.2.2 Concept Evaluation

For the design of radar, users liked the idea of inserting the radar into the wristband, that is why concept 1 got the highest score. Take the radar out to use it, put it back to charge it. From the users' perspective, this idea was futuristic and more convenient than attaching the radar on the wristband surface. However, two users mentioned the screen of concept 1 is too small.

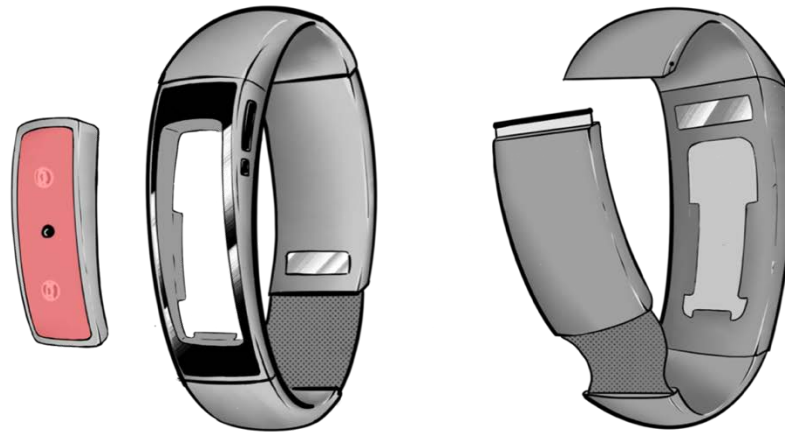
Concept 3 got second place. The upper and lower sides of the wrist are where users preferred to feel the vibrations. When feeling the vibrations, a larger touching area means higher accuracy. But two users were afraid of losing the sensor since it is attached to the wristband's outer surface, and the radar might be an obstacle when they do other things. Users also like using the radar as the taillight.

score	like					
	dislike					
User 1 female	3	<p>The sensor can be integrated into the wrist band. Won't lose the sensor.</p> <p>The interface is too small, maybe users cannot get enough visual information.</p>	5	<p>The interface is big enough, users can also get other information like time and weather.</p>	3	<p>The interface is big enough, users can also get other information like time and weather.</p> <p>The way how the sensor be connected to the wrist band is difficult to understand.</p>
User 2 female	5	<p>I like how the sensor and wrist band be put together. They're like an integral whole.</p>	2	<p>I'm afraid of losing the sensor.</p>	4	<p>I like the design of that slope, it will help users better see the color without reflections on the screen.</p> <p>I'm afraid of losing the sensor.</p> <p>The sensor looks not that fit the shape of bike tube.</p>
User 3 male	4	<p>I like how it look, it reminds me of airpods. It is very trending.</p> <p>However, the screen is too small for me. I cannot use it as a watch.</p>	3	<p>It has a big screen, which is good.</p> <p>Since I have the sensor on the other side of my wrist, it might be uncomfortable to wear.</p>	5	<p>I like the way it put the vibrating discs. It will help me better feel the vibration.</p> <p>It looks hard to disassemble.</p> <p>I like the size of that interface, so that I can see the time.</p>
User 4 female	5	<p>I like how the radar sensor and the wrist band be integrated. It looks good no matter I put the sensor back or not.</p>	2	<p>If I put the sensor back, it might be a obstacle when I do things.</p>	4	<p>I think the design of the screen is good, it can help me better view the information.</p> <p>If I put the sensor back, it might be a obstacle when I do things.</p> <p>It might be hard to take the sensor off and put it back.</p>
		17	12	16	14	

3.3 Selected Concept

Based on the concept evaluation results, I combined concept 1 and concept 3 as our final direction.

The wristband doesn't need a very big screen since it only provides colors. However, to let users clearly see the color, the screen will be larger than the concept 1. The radar should be able to put back inside the wristband, it is more convenient than attaching the radar on the surface. The two haptic engines should touch the upper side and lower side of users' wrist. Because more contact space can help users better feel the vibrations. Last but not least, it's good to have the radar work as a taillight. The wristband adopts the accelerometer sensor to sense the user's acceleration and direction. Users can wear it on either wrist, it will always provide traffic information on the correct side.



3.4 Technology Exploration & Concept Refine

3.4.1 Method and Purpose

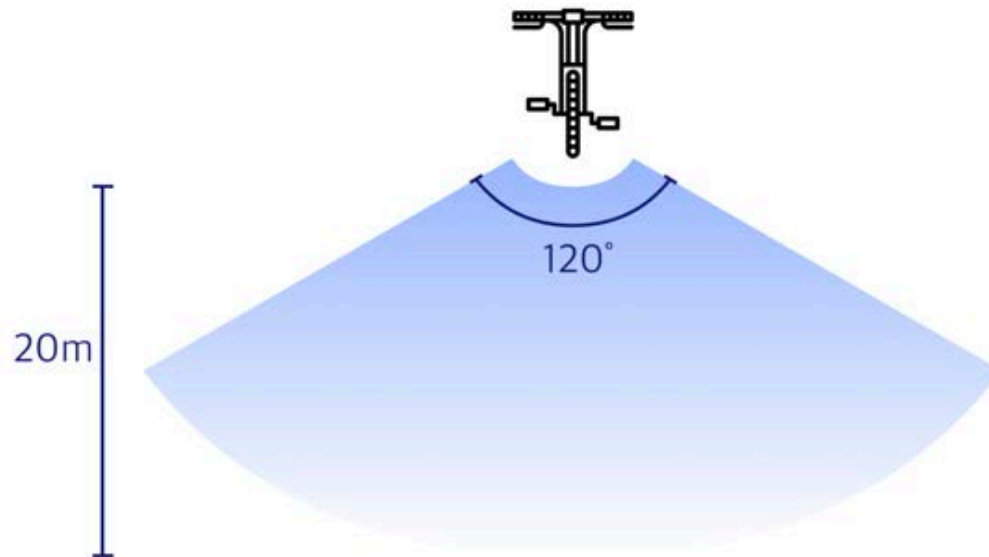
Now I have a clear and beautiful vision of the project. However, as designers, I also need to consider the feasibility. Can our current technology support this idea? Otherwise, this idea is just a castle in the air...

I did the technology exploration, looked up different trending products, and picked the digital elements that could fulfill our functions. The concept was refined based on the exploration results.

3.4.2 Radar Transceiver System on Chip (RTSC)

RTSC is the soul of this project. Compared to the normal radar, microwave radar has higher accuracy and longer detect distance. After looking up and compared RTSC from different companies, I picked AWR1642 from Texas Instruments (10.4mm x 10.4mm x 0.65mm) as the ideal radar chip for our design.

It is a 76 - 81GHz single-chip radar transceiver system. After programming, it can work as a Short-Range Radar. Objects could be detectable from 20 meters away with the resolution of 4.3 cm. The detect angle could be $\pm 60^\circ$ with the angular resolution of approximately 15° . [16]



3.4.3 Other Digital Elements

	small storage battery	haptic engine	radar transceiver system	mini bluetooth module	Linear Voltage Regulator	LCD color display	mini LED light bulb
existing technology	battery in Airpods 1 Charging Case	Taptic Engine for Apple Watch 5	AWR1642 from Texas Instruments	SESUB-PAN-T2541 from TDK Corporation	LP3990-Q1 from Texus Instruments	PDI09601A-V3 from Phoenix Display	Lighthouse LEDs
size	6mm /21mm /36mm	< 5mm /11mm /27mm	10.4mm x 10.4mm x 0.65mm	4.6mm x 5.6mm x 1.0mm	1.324mm x 1.045mm (MAX)	13.30mm x 27.948mm x 1.4mm	5mm x 5mm x 12mm
battery capacity	398 mAh	—	—	—	—	—	—
working voltage	3.81 V	3.81 V	1.8 – 3.3V	—	input 2.0v-6v output 0.8v-3v	3.15V to 5V	3.0-3.4v

The link to these digital elements is listed in reference. [14][15][16][17][18][19][20]

3.4.4 Concept Refinement

Based on the results, here I had some adjustments to our design:

Change 1: Considering the size and the power consumption of the mini LED light bulb, the design concept will not have the taillight function at this point.

Change 2: The radar detector will need a special holder to get attached to the bike seat post.

3.5 Final Concept

3.5.1 Needed Digital Elements

Based on the product functions, I listed the digital elements that might be needed.

	wrist band			
	wrist band battery	mini bluetooth module	haptic engine	LCD color display
number	1	1	2	2
size	6mm /21mm /36 mm	4.6mm x 5.6mm x 1.0mm	< 5mm /11mm /27mm	13.30mm x 27.948mm x 1.4mm
battery capacity	398 mAh	—	—	—
working voltage	3.81 V	3.0–3.4v	3.81 V	3.15V to 5V
power consumption	—	20 mW	—	—

	radar detector			
	mini bluetooth module	Linear Voltage Regulator	radar transceiver system	radar detector battery
number	1	1	1	1
size	4.6mm x 5.6mm x 1.0mm	1.324mm x 1.045mm (MAX)	10.4mm x 10.4mm x 0.65mm	6mm /7mm /12mm
battery capacity	—	—	—	132 mAh
working voltage	3.0–3.4v	input 2.0v–6v output 0.8v–3v	1.8 – 3.3V	3.81 V
power consumption	20 mW	—	< 120 mW	—

3.5.2 Possible Product Size

I got the size of each digital element; it wasn't too hard to get the approximate size of our final design.

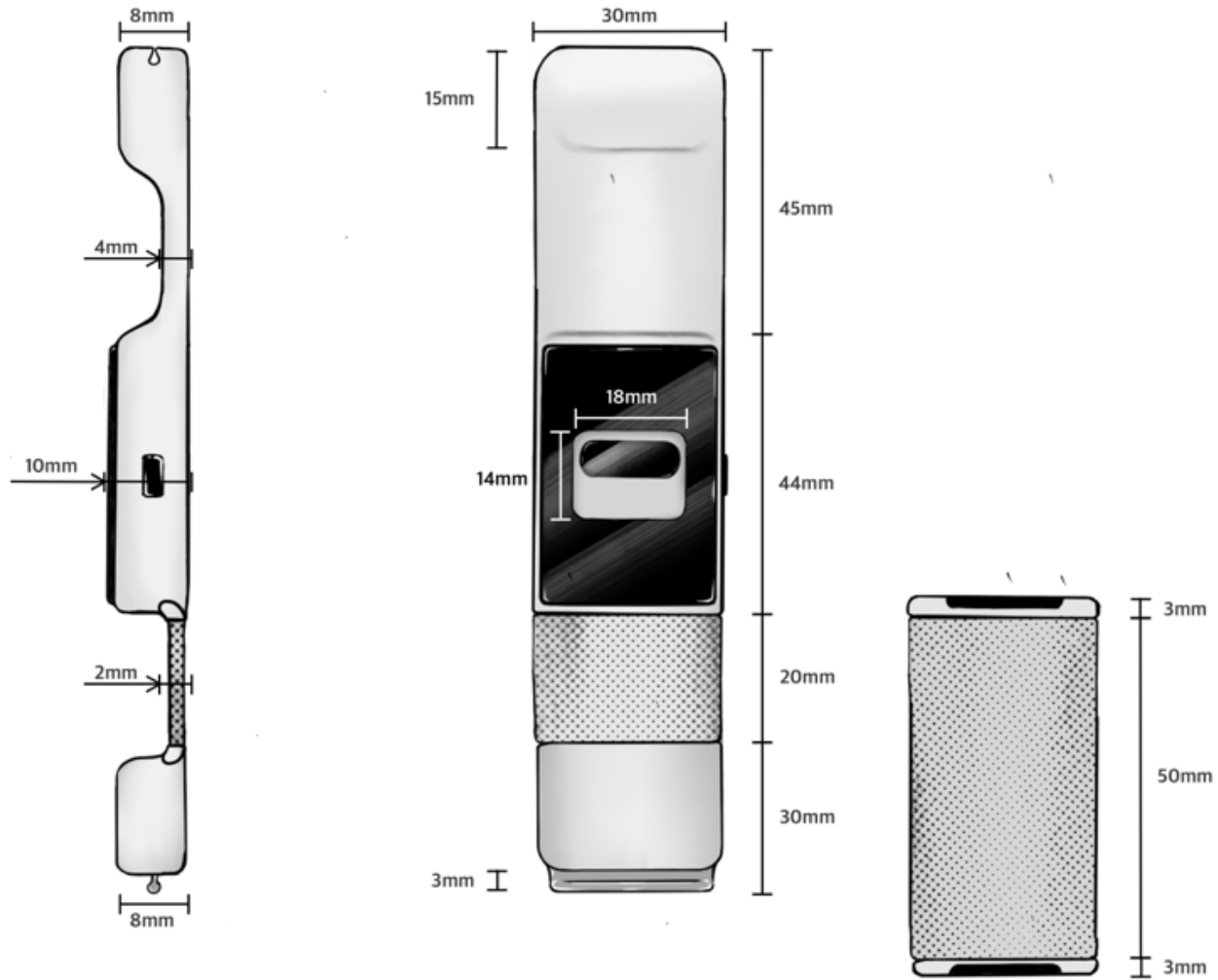
Based on the Market Research, I'm going to provide two sizes of Spandex belt. Since the rebound rate of Spandex is 100% when stretched to 5 times, the shorter one (20cm) could work for wrist circumference from 130mm-170mm, and the longer one (50cm) will work for wrist circumference from 160mm-260mm. [21]

I also provide five sizes of the special seat post clamp for users to pick the proper one. [22]
Users can pick the most suitable one when they order the product on our website.

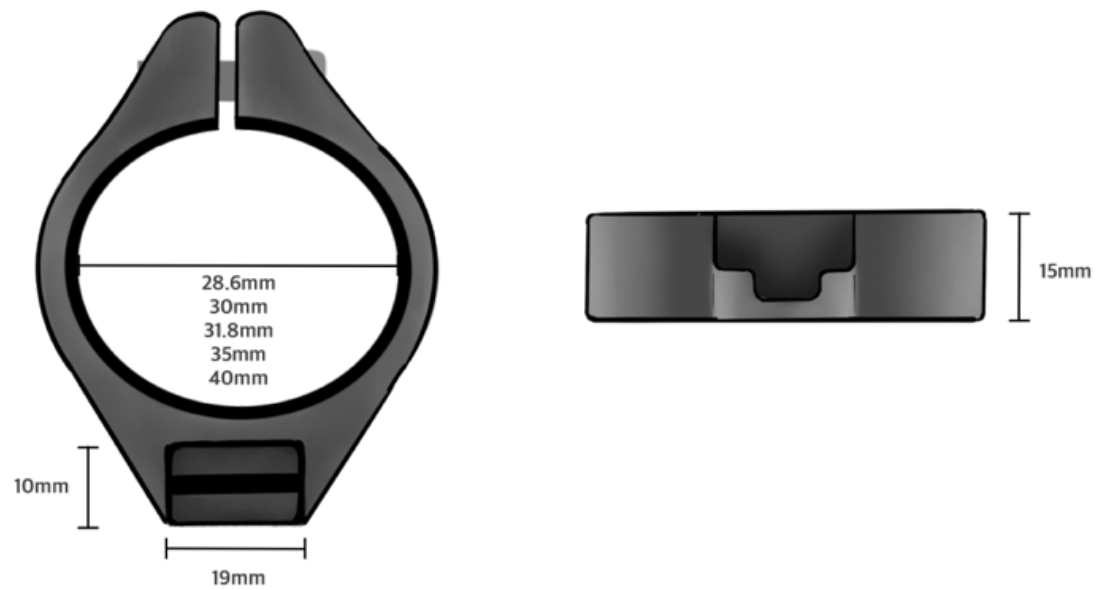
	the 'watch'	radar detector	buckle with battery inside	soft silica belt	spandex belt	
number	1	1	1	1	1	1
size	30mm x 44mm x 10mm	18mm x 14mm x 9mm	30mm x 20mm x 8mm	30mm x 45mm x 8mm / 4mm	S/M (130mm—170mm) 30mm x 20mm x 2mm	M/L (160MM—260) 30mm x 50mm x 2mm

	the radar detector holder	the seatpost clamp				
number	1	1	1	1	1	1
size	19mm x 10mm x 15mm	diameter 28.6mm x height 15mm	diameter 30mm x height 15mm	diameter 31.8mm x height 15mm	diameter 35mm x height 15mm	diameter 40mm x height 15mm

Wristband & Radar



Seat post clamp



3.5.3 Detailed Sketches

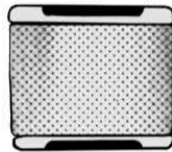
the main body of wrist band



radar detector



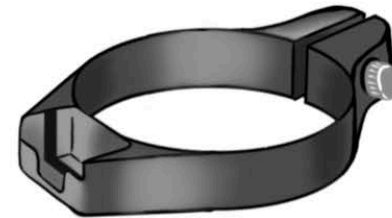
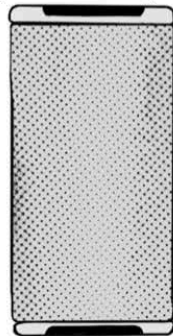
spandex belt (s/m)



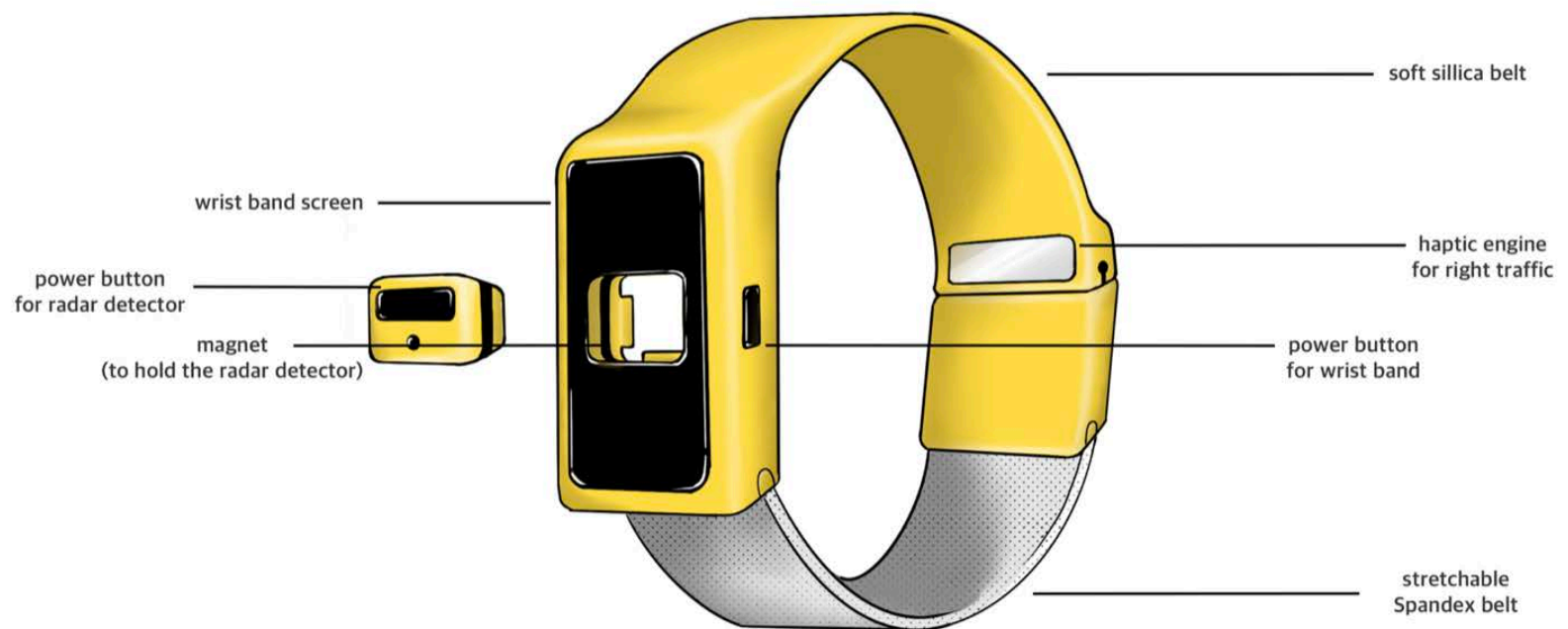
battery buckle

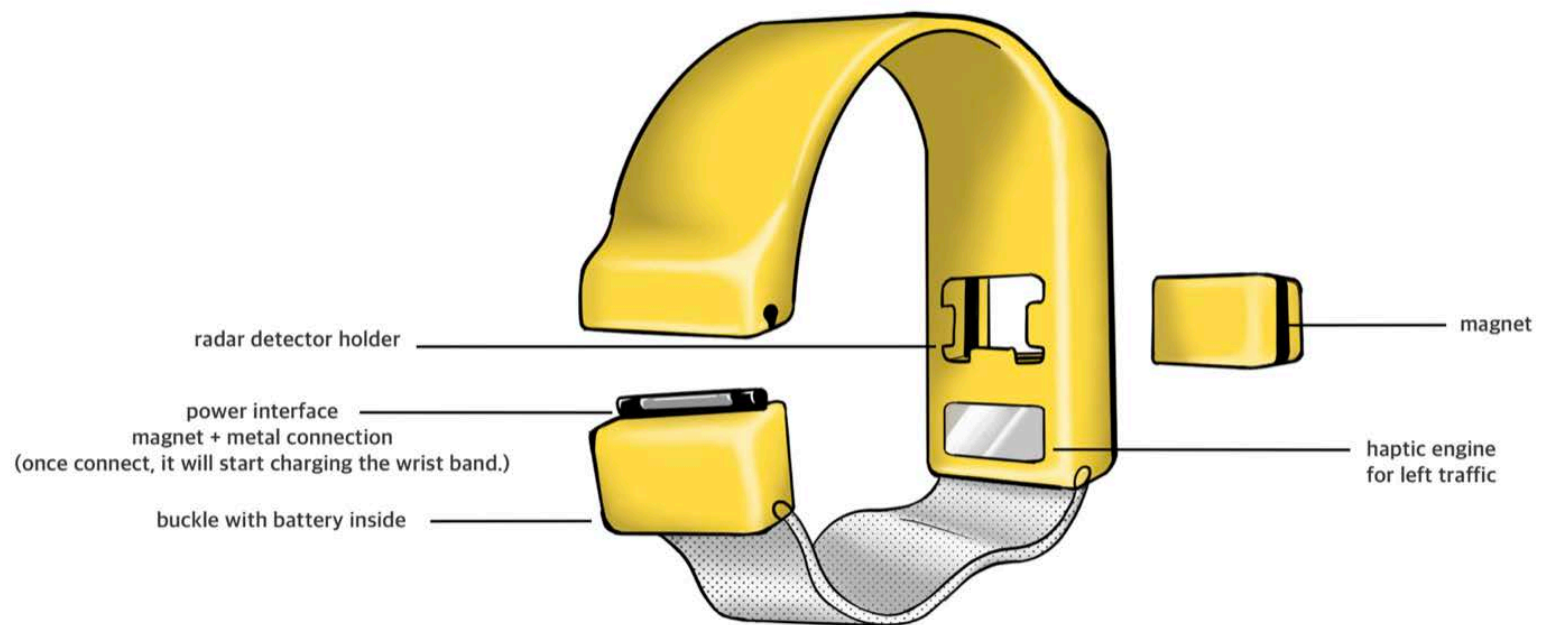


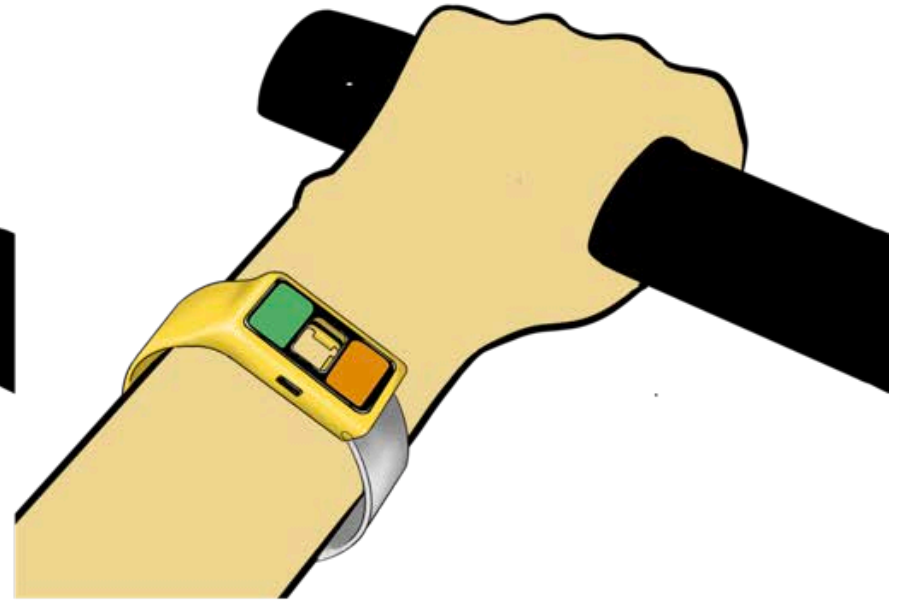
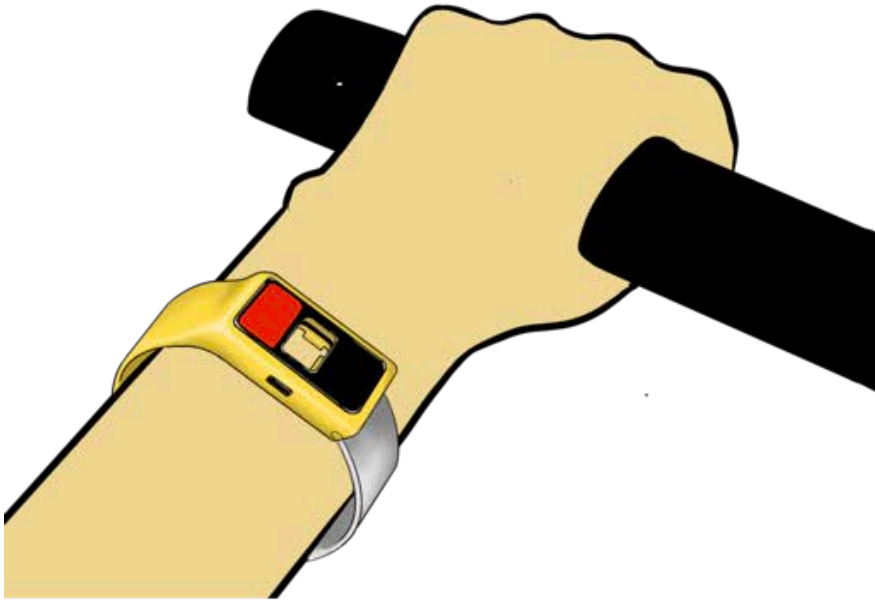
spandex belt (m/l)

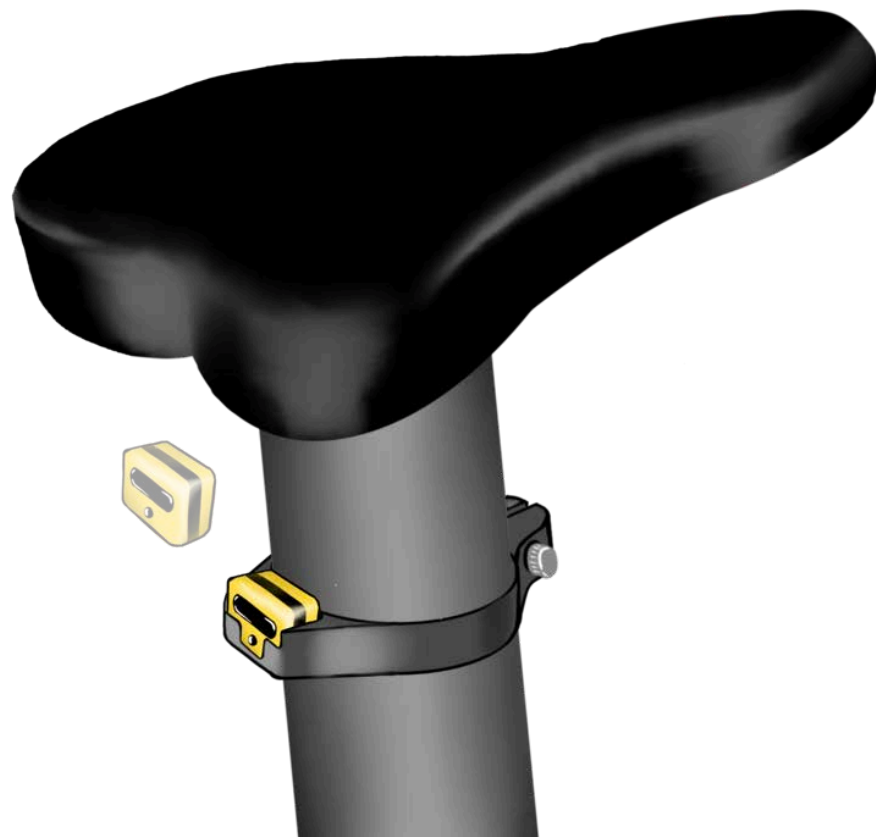


radar detector holder
(seat post clamp)



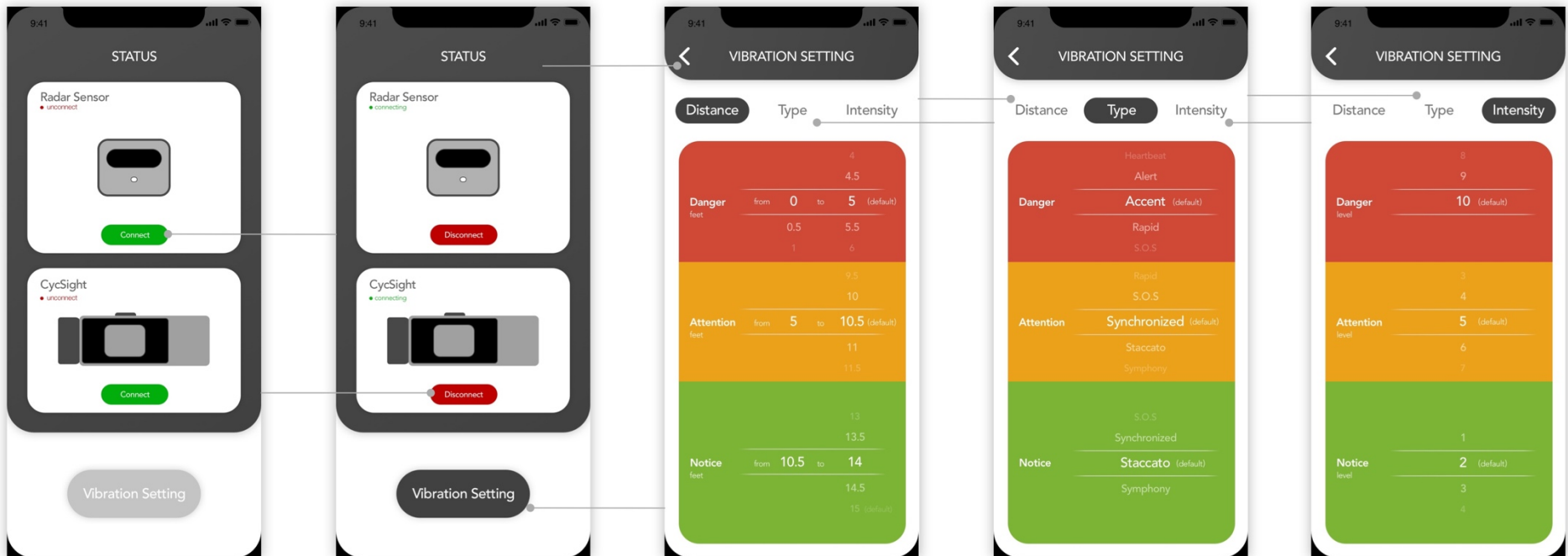






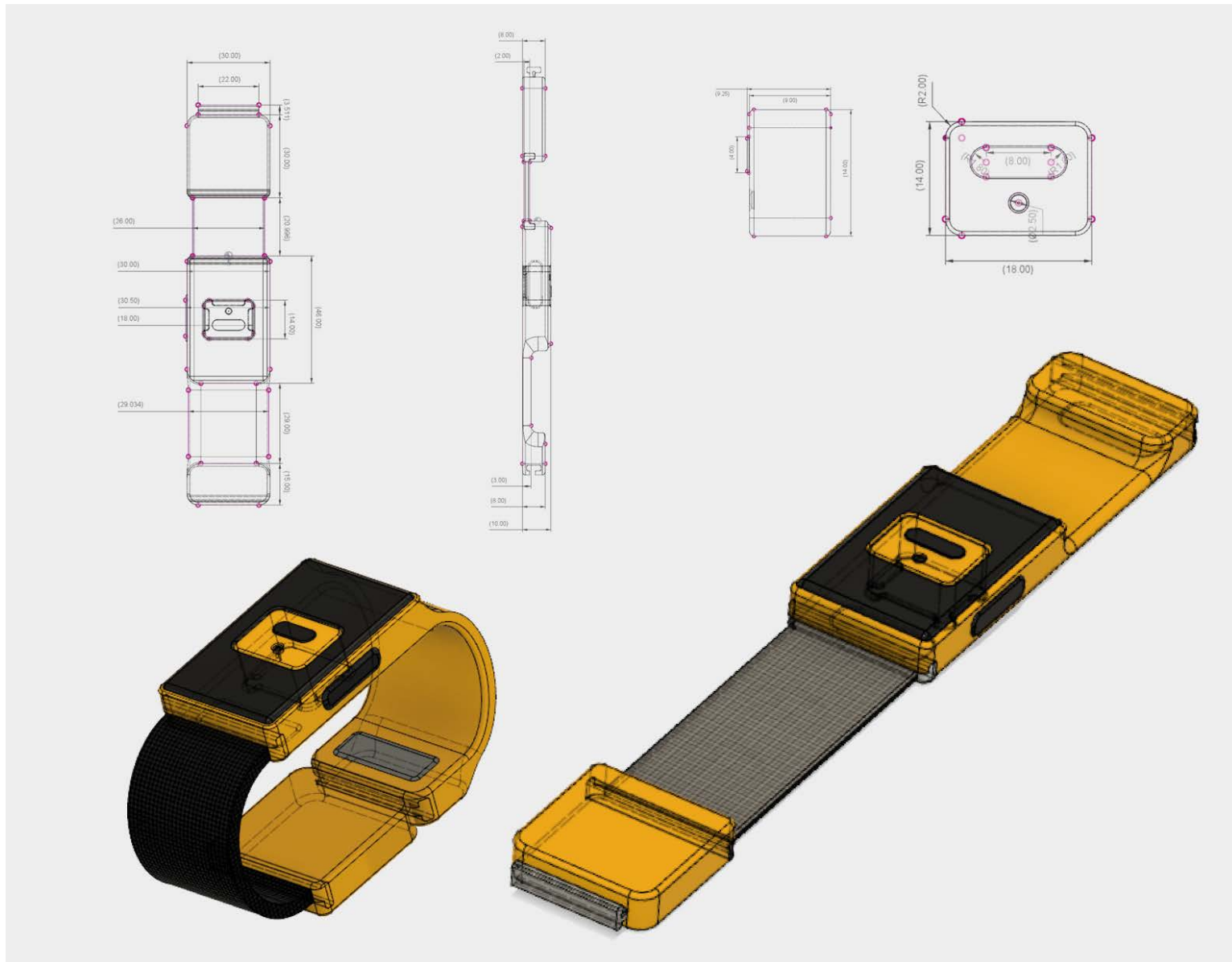
3.6 App Design

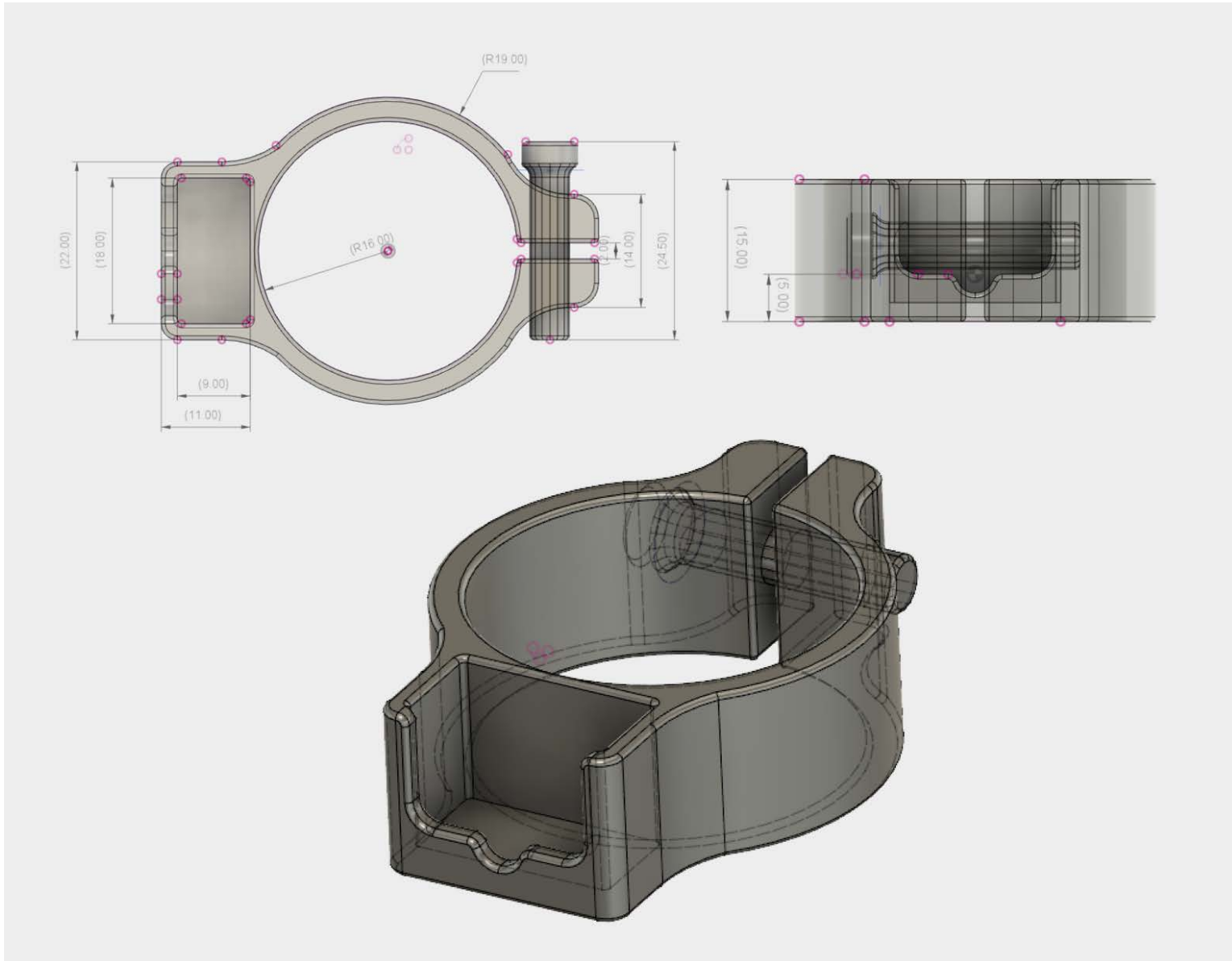
To better improve users' experience, I provided this app to let users customize the signals. They can adjust the range of each zone as well as the vibration pattern and intensity. The wristband will provide them real-time feedback during the whole process.



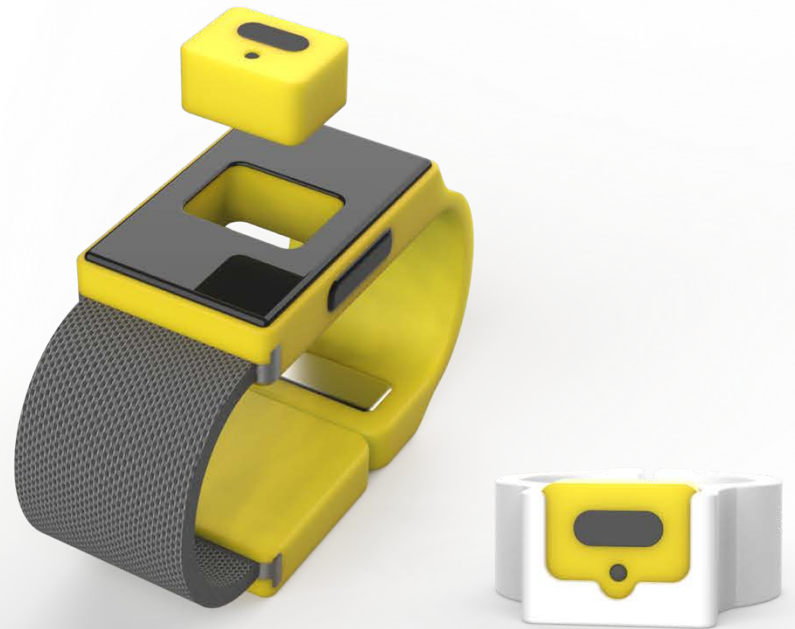
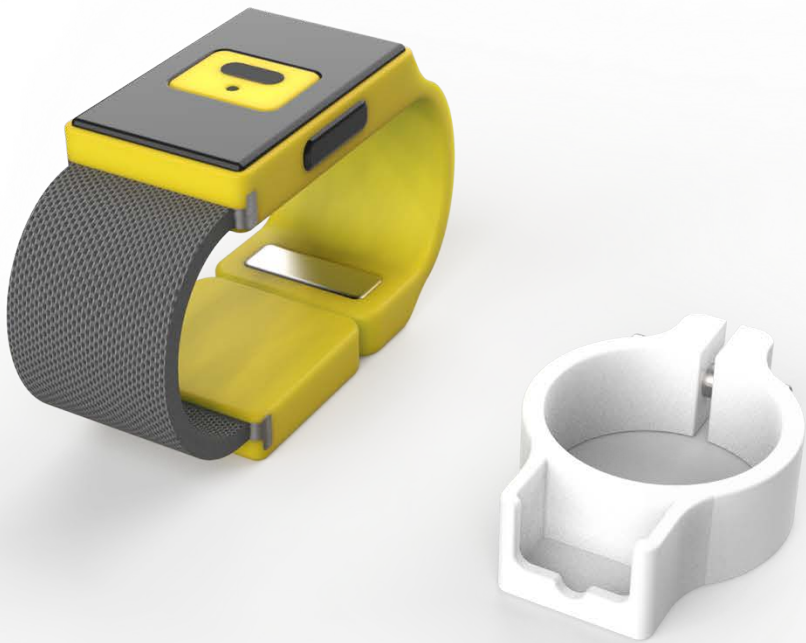
PROTOTYPE

4.1 CAD Model





4.2 Rendering







4.3 Physical Model



3D Printing



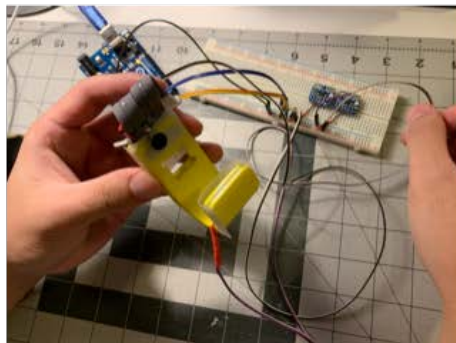
Sand



Assemble



Simulate Vibration



Paint



Make Elastic Belt



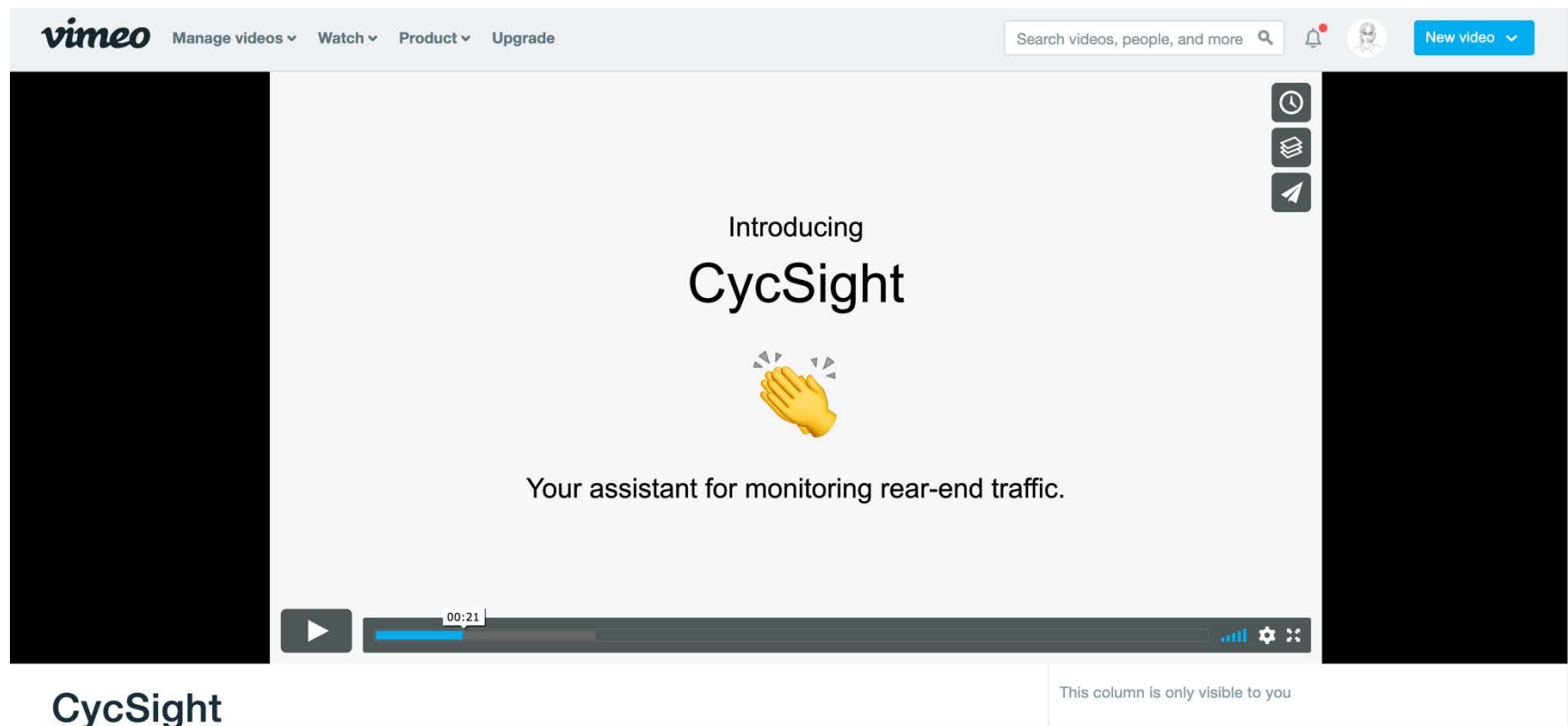




4.4 Introduction Video

I planned to do an online expert review with hearing-impaired cyclists. To better explain our idea, I made this video and shared it with hearing-impaired cyclists.

Vimeo link: <https://vimeo.com/438229222>



EVALUATION

5.1 User Test

5.1.1 Method and Purpose

As a user-centered design project, our goal is to achieve a product that maximumly meets users' needs and acknowledge. No doubt that users' participation is the best way to find out the usability problems, evaluate the design, and help us refine it.

The test contained five main sections; each section aimed to investigate one aspect of this design:

- 1) Users' basic info
- 2) The physical appearance of CycSight
- 3) The function of CycSight
- 4) The UI & function of CycSight App
- 5) The overall score for CycSight

7 participants who had cycling experience were invited. Before the test, participants were allowed to explore the device and interface freely. After that, they were asked to answer 7 questions and finish 4 quick tasks. All of their test results and feedbacks were documented.

5.1.2 Tasks and Questions

Part 1. User basic info

- 1) How long have you been cycling?

Part 2. The physical appearance of the device

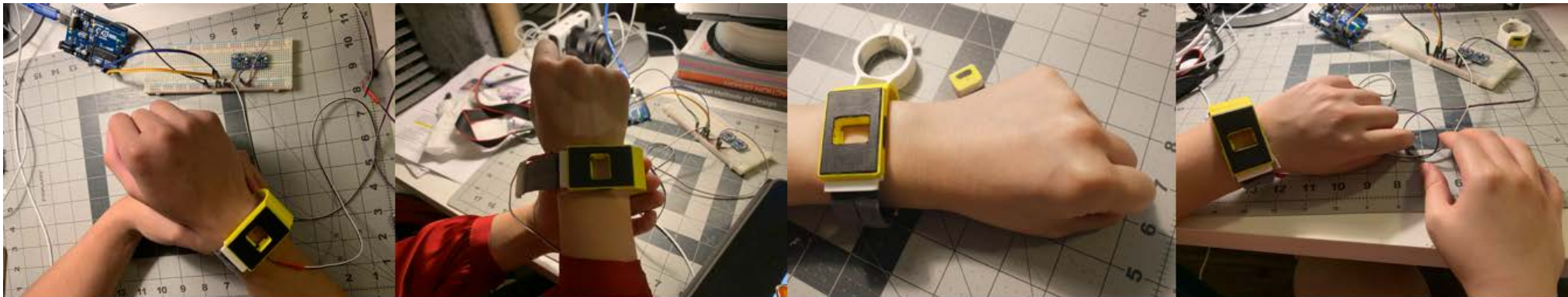
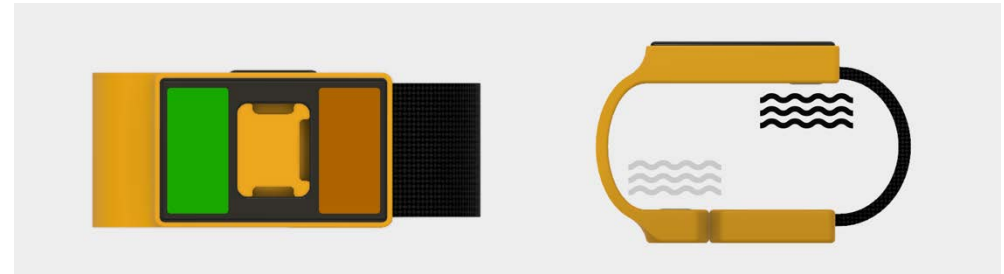
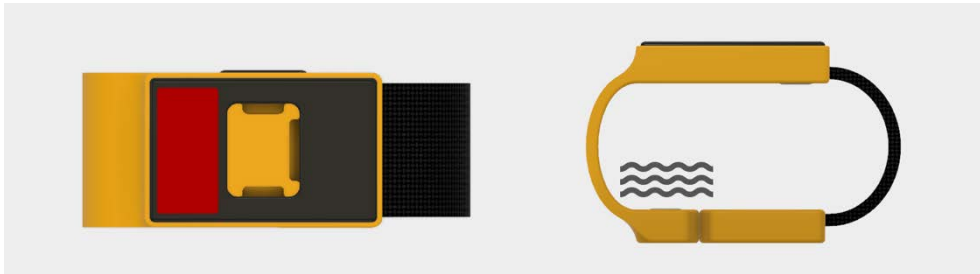
- 1) How do you like the appearance of CycSight? On a scale from 1 to 5, please rate each component. (1 = very dissatisfied; 5 = very satisfied)
 - a) Wristband
 - b) Radar
 - c) Seat post clamp
- 2) Do you understand how to wear/assemble CycSight? On a scale from 1 to 5, please rate each component. (1 = very dissatisfied; 5 = very satisfied)
 - a) Wristband
 - b) Radar
 - c) Seat post clamp



Prototype Exploration & Try On

Part 3. The function of the device

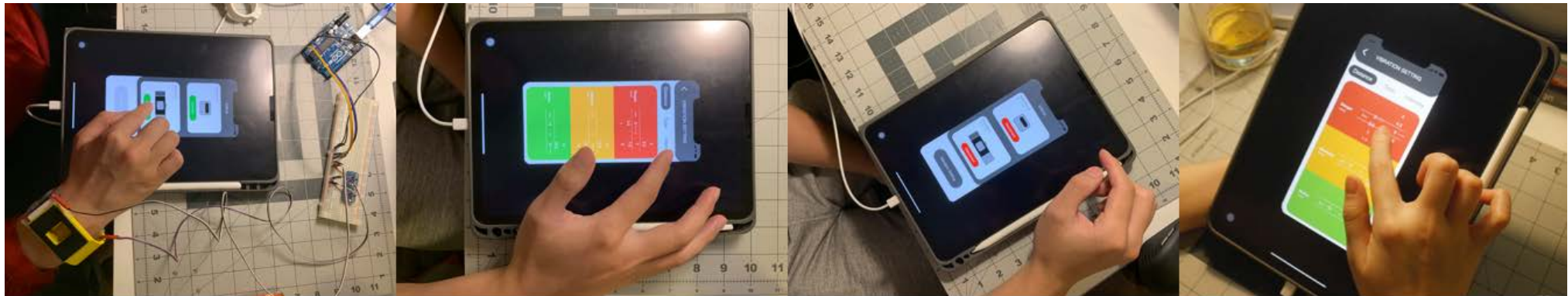
- 1) Now you are cycling on a busy street, the status of CycSight wristband is like the left picture (play vibration at the same time). Please describe the condition of the vehicle behind.
- 2) Now you are cycling on a busy street, the status of CycSight wristband is like the right picture (play vibration at the same time). Please tell me which vehicle is closer to you?



Feel Vibrations

Part 4. The UI & function of the app (time was recorded)

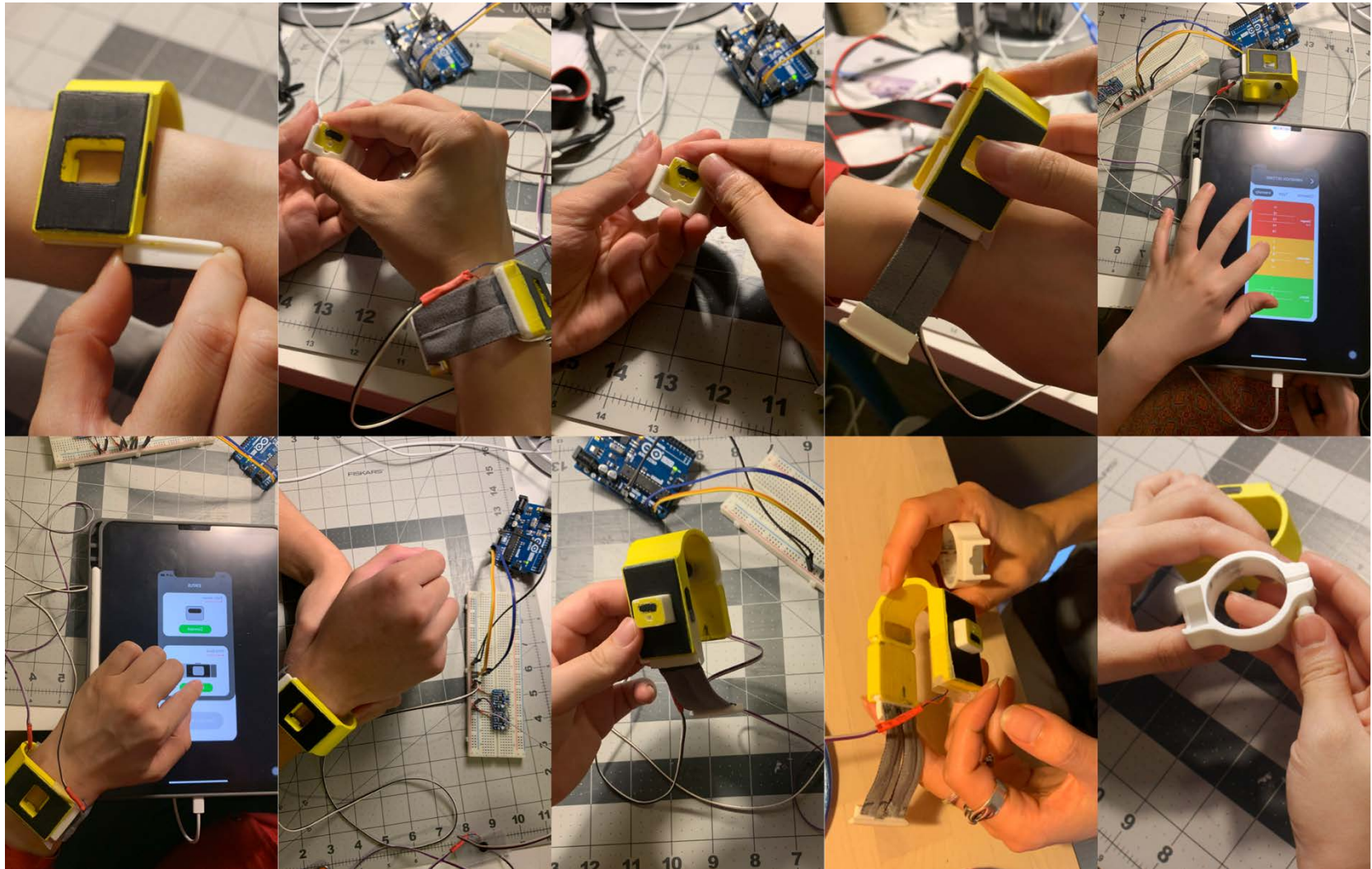
- 1) Task 1: Please connect CycSight to the app.
- 2) Task 2: Please adjust the range of Danger Zone to 0 – 9 meters; adjust the range of Attention Zone to 9 – 17 meters.
- 3) Task 3: Please adjust the vibration type of Attention Zone to 'Quick'; adjust the vibration type of Notice Zone to 'Bamboo'.
- 4) Task 4: Please adjust the vibration intensity of Danger Zone to level 14; adjust the vibration intensity of Notice Zone to level 9.
- 5) How do you like the UI? On a scale from 1 to 5, please rate. (1 = very dissatisfied; 5 = very satisfied)
- 6) How do you like the function of this app? On a scale from 1 to 5, please rate. (1 = very dissatisfied; 5 = very satisfied)



Test App Prototype

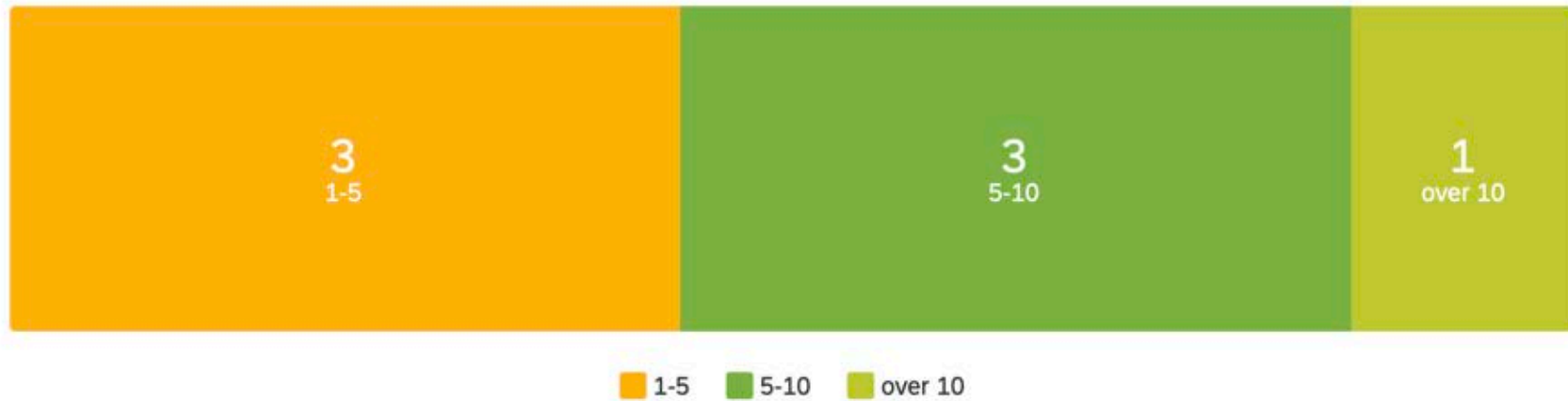
Part 5. The overall score

- 1) Overall, how do you like CycSight? On a scale from 1 to 5, please rate. (1 = very dissatisfied;
5 = very satisfied)



5.1.3 Test Results & Feedback

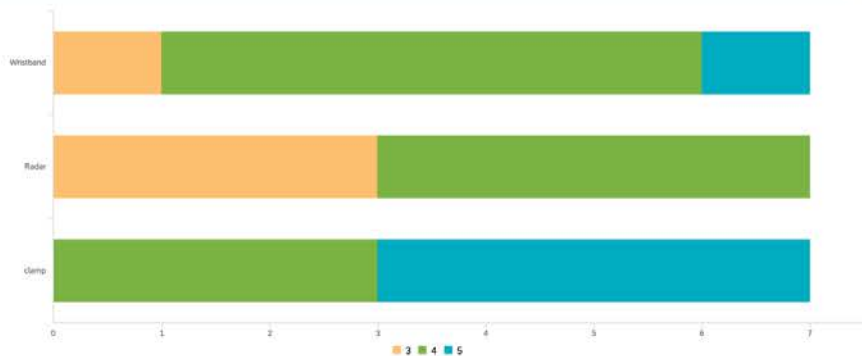
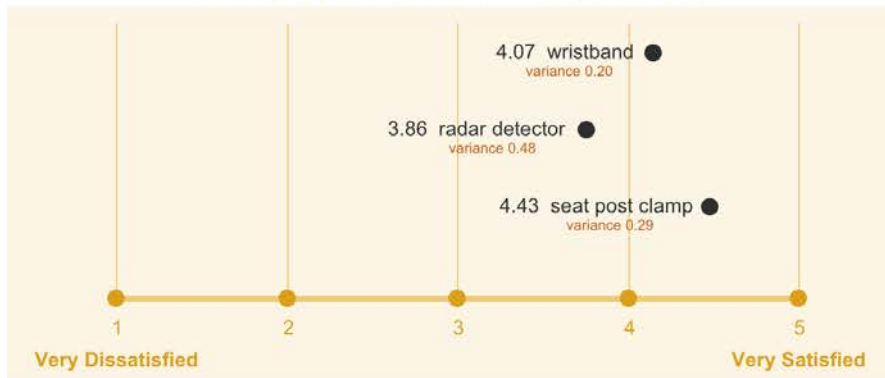
Part 1. Users Basic Info



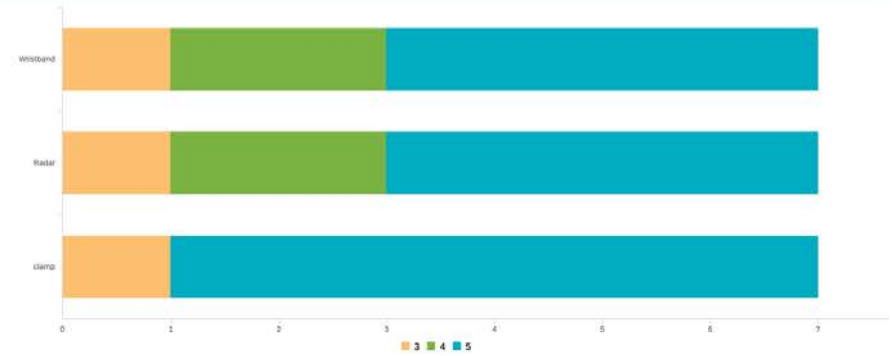
Due to the Covid-19, I could only invite my friends who could be confirmed healthy to do the in-person user test. All of them have cycling experience. Although they didn't have hearing loss, they could still provide me constructive feedback on the physical design and the app design from the cyclist's perspective.

Part 2. Physical Appearance

PHYSICAL APPEARANCE



PHYSICAL USAGE



Feedback:

- 1) Two users mentioned that there's no need to desperate the battery from the wristband's main body.
- 2) Three users think the current design of belt and buckle is not 'one-hand' friendly, they think it could be improved.
- 3) Though they think the idea of putting radar inside the wristband is very cool, two users didn't like the hole in the middle of the wristband.

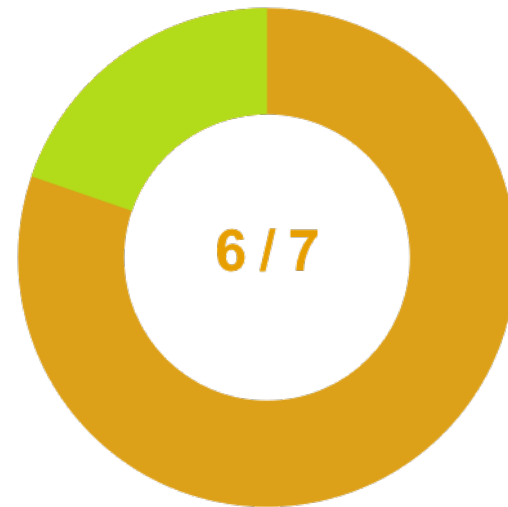
Part 3. Key Functions

QUESTION 1



■ Correct
■ Wrong

QUESTION 2

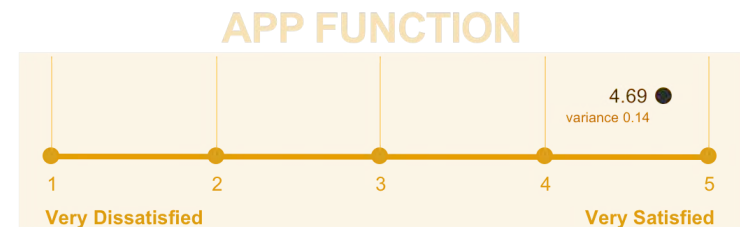
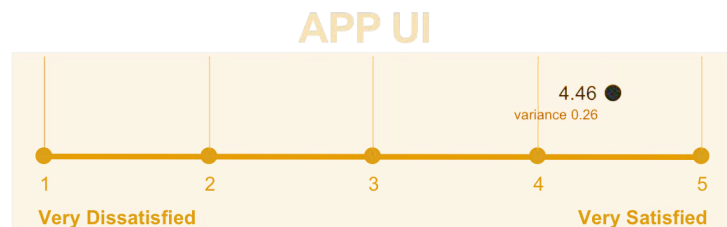
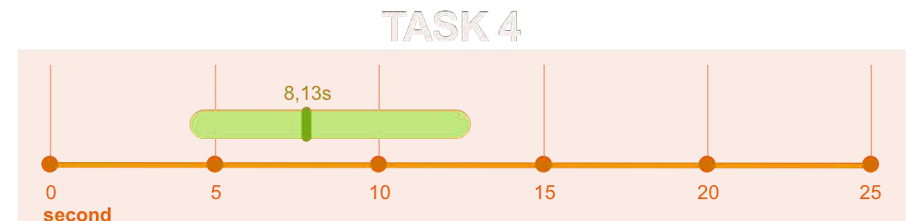
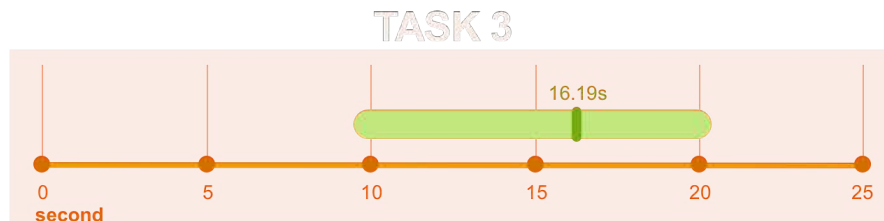
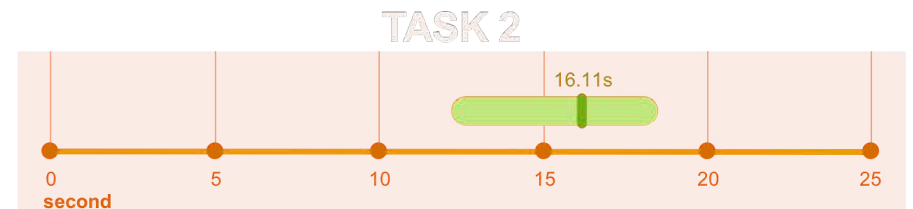


■ Correct
■ Wrong

Feedback:

- 1) Only one user gave the wrong answer in question 2, but he corrected the answer in a few seconds. Users thought the combination of vibration and color is easy to understand. But they wondered how the vibrations would work in real conditions.
- 2) One user mentioned that several colors make him confused, he would prefer just one color with different shades.

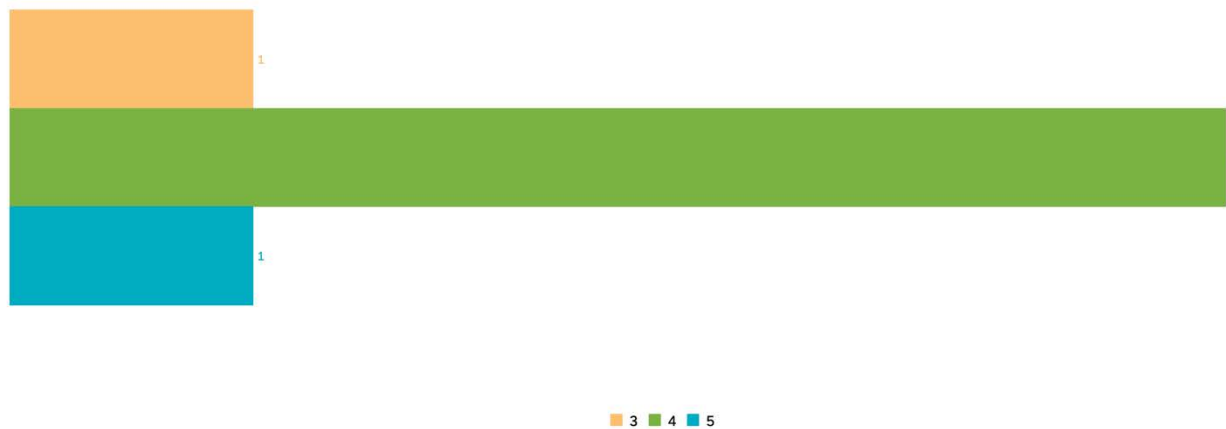
Part 4. UI & Functions of App (time was recorded)



Feedback:

- 1) Users were satisfied with the APP's UI and functions; they thought the workflow is smooth and functions are easy to understand.
- 2) The App needs to have guidance and unit conversions.
- 3) Four users preferred to connect radar and wristband with only one click.

Part 5. Overall Score



5.1.4 Insights

Users thought the idea of integrating radar into the wristband is cool and convenient, which reminded them of AirPods. As cyclists, vibration was what they preferred. However, from their feedback, I still find some limitations about the current physical design:

- The physical design of belt and buckle need to be improved.
- I have to think about how to fix the hole the radar left.

For the app, Users thought the App was necessary to the whole design, the UI was satisfying, and the workflow was smooth. To provide a better user experience, I need to add the guidance and unit conversions.

From the user test, I also see the potential direction of clean energy. By generating cyclists' motion, we could power the radar.

5.2 Online Expert Review

5.2.1 Method and Purpose

Although I have got the user test with people who have cycling experience, I still saw the necessity of doing an expert review with hearing-impaired cyclists. I uploaded the introduction video to Vimeo and made an evaluation survey with Qualtrics. By clicking the link, participants would be able to watch the video and do the survey online.

I communicated with the president of the Deaf Seniors of America Association. He helped us send the link to those members who registered as hearing-impaired cyclists. Finally, I got 16 responses.

Since participants couldn't take a close look at the prototype, the evaluation survey was more focused on investigating their acceptance of CycSight and how CycSight meets their acknowledge. Participants could look from a higher perspective to rate CycSight and share their thoughts.

5.2.2 Process and Questions

Part 1. Introducing CycSight

- 1) Participants were asked to watch the video before taking the survey.

Vimeo link: <https://vimeo.com/438229222>

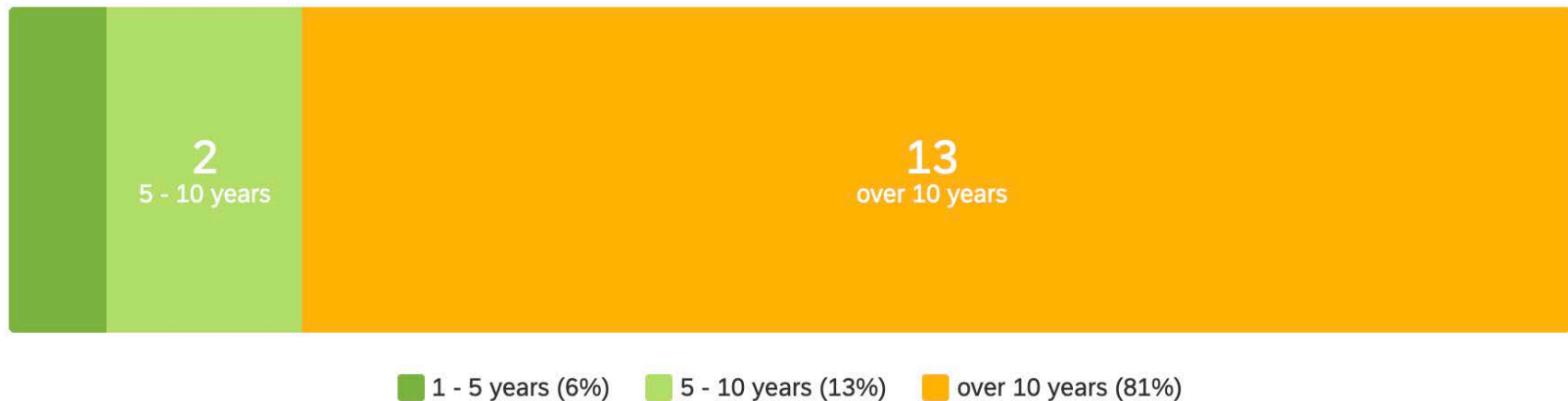
Evaluation form: https://gatech.co1.qualtrics.com/jfe/form/SV_a5m00ffb3vLosR

Part 2. Taking Evaluation Survey

- 1) How many years have you been cycling?
 - a) 1 – 5 years
 - b) 5 – 10 years
 - c) Over 10 years
- 2) How do you like the appearance of CycSight? On a scale of 1 to 5, please rate each component. (1 = very dissatisfied; 5 = very satisfied)
- 3) Do you understand how to use CycSight? On a scale of 1 to 5, please rate each component. (1 = very dissatisfied; 5 = very satisfied)
- 4) How do you like the way (Haptic + Visual) CycSight express information? On a scale of 1 to 5, please rate. (1 = very dissatisfied; 5 = very satisfied)
- 5) Overall, do you think CycSight can improve hearing-impaired cyclists' road safety? On a scale of 1 to 5, please rate. (1 = very dissatisfied; 5 = very satisfied)
- 6) Please give us your thoughts on CycSight. Any feedback is valuable.

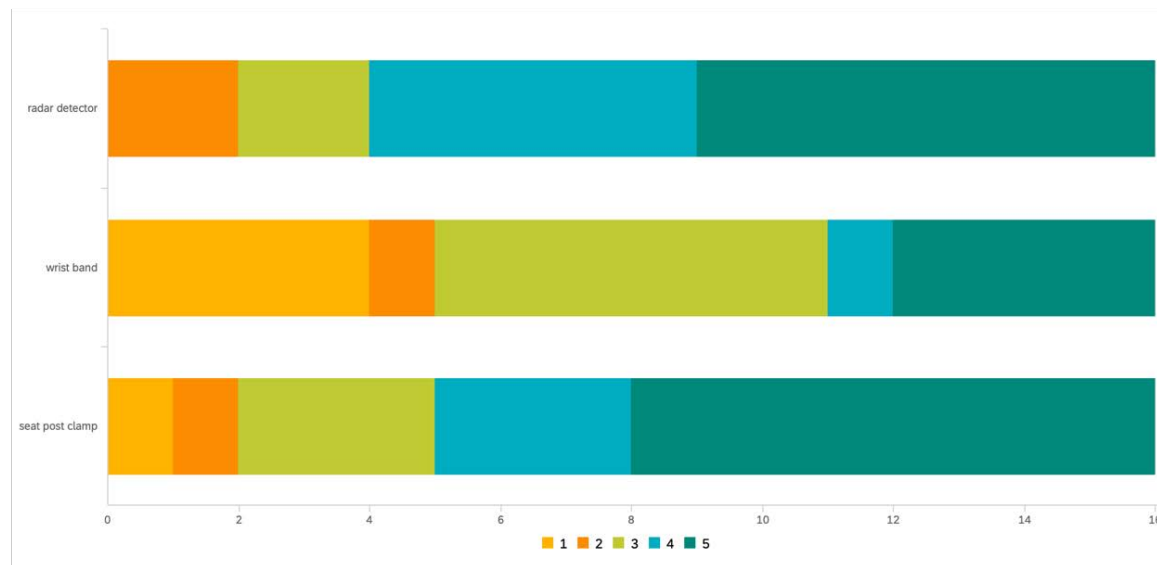
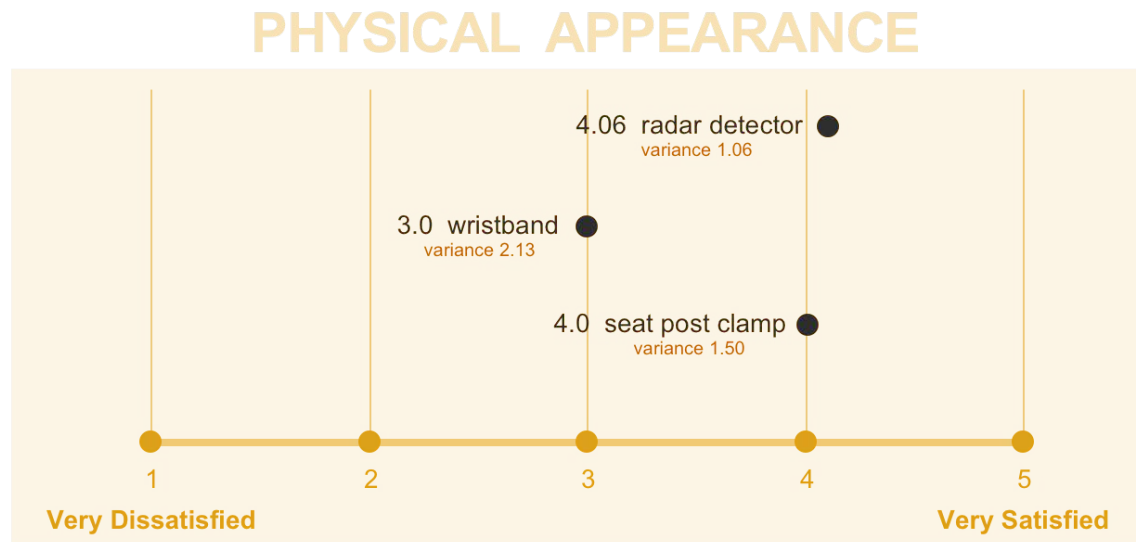
5.2.3 Expert Review Results & feedback

Question 1. User Basic Info



All participants were hearing impaired cyclists from the Deaf Senior of America Association. The majority of them have more than 10 years of cycling experience. Due to the Covid-19, it was impossible to invite them to try on and review CycSight in person. However, with the online survey, they could still rate the design from a macro perspective and share their thought.

Question 2. Physical Appearance



Feedback:

1) The scores for wristband were polarized, and four participants gave it 1.

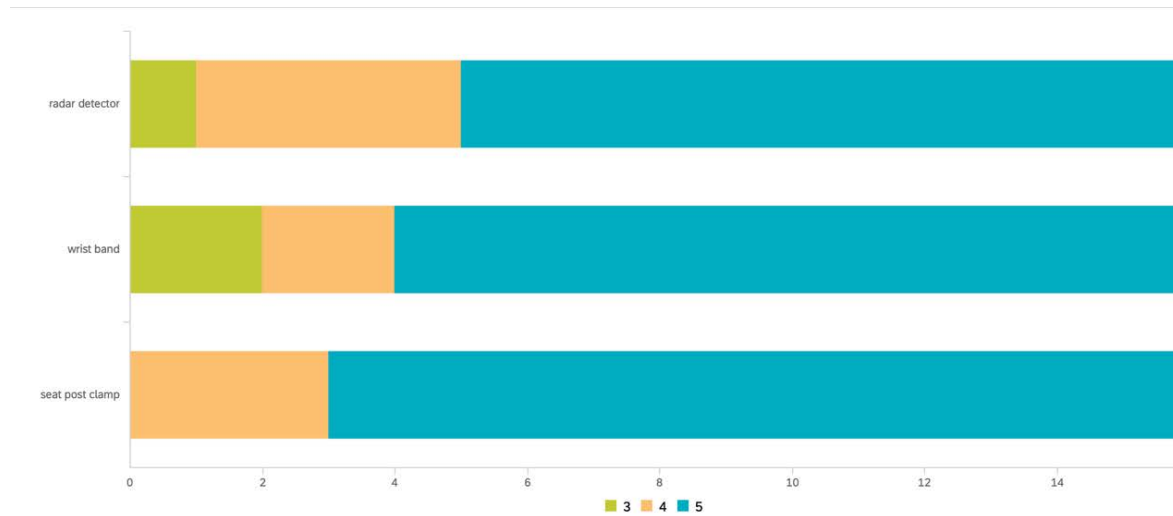
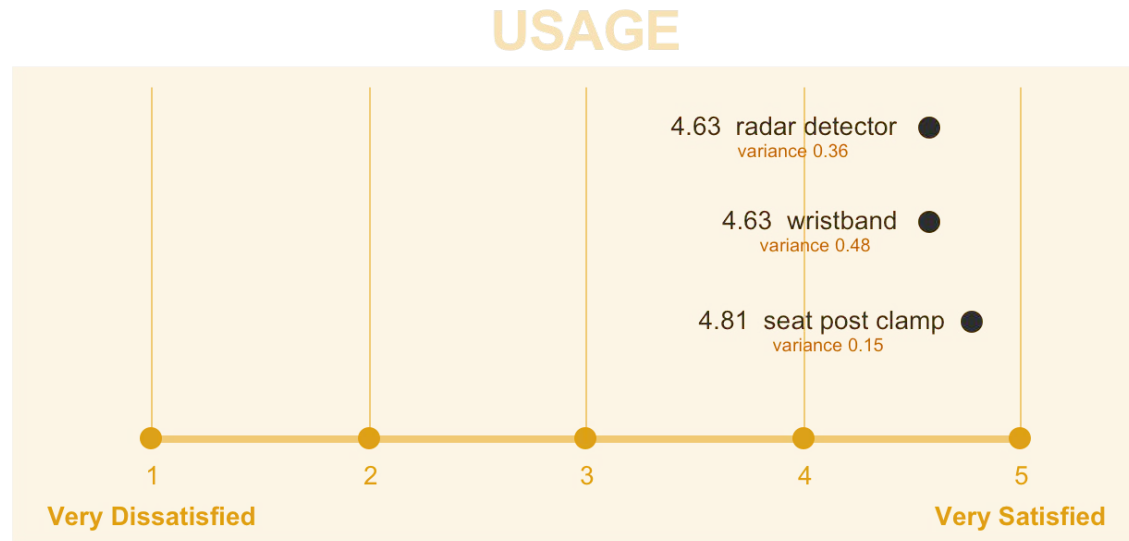
Below are the comments from these four participants:

- "I really like the idea, but I wouldn't wear a wristband since I already wear a watch..."
- "I already have my Road ID and GPS watch there."
- "I think it is the wrong approach and we need to build more bike lanes instead."
- "This isn't as appealing to me."

As long-term cyclists, they needed their wristbands to have more sport-related functions like GPS, heart rate monitoring, and calorie consumption monitoring.

2) Two users mentioned that we could integrate a taillight in CycSight.

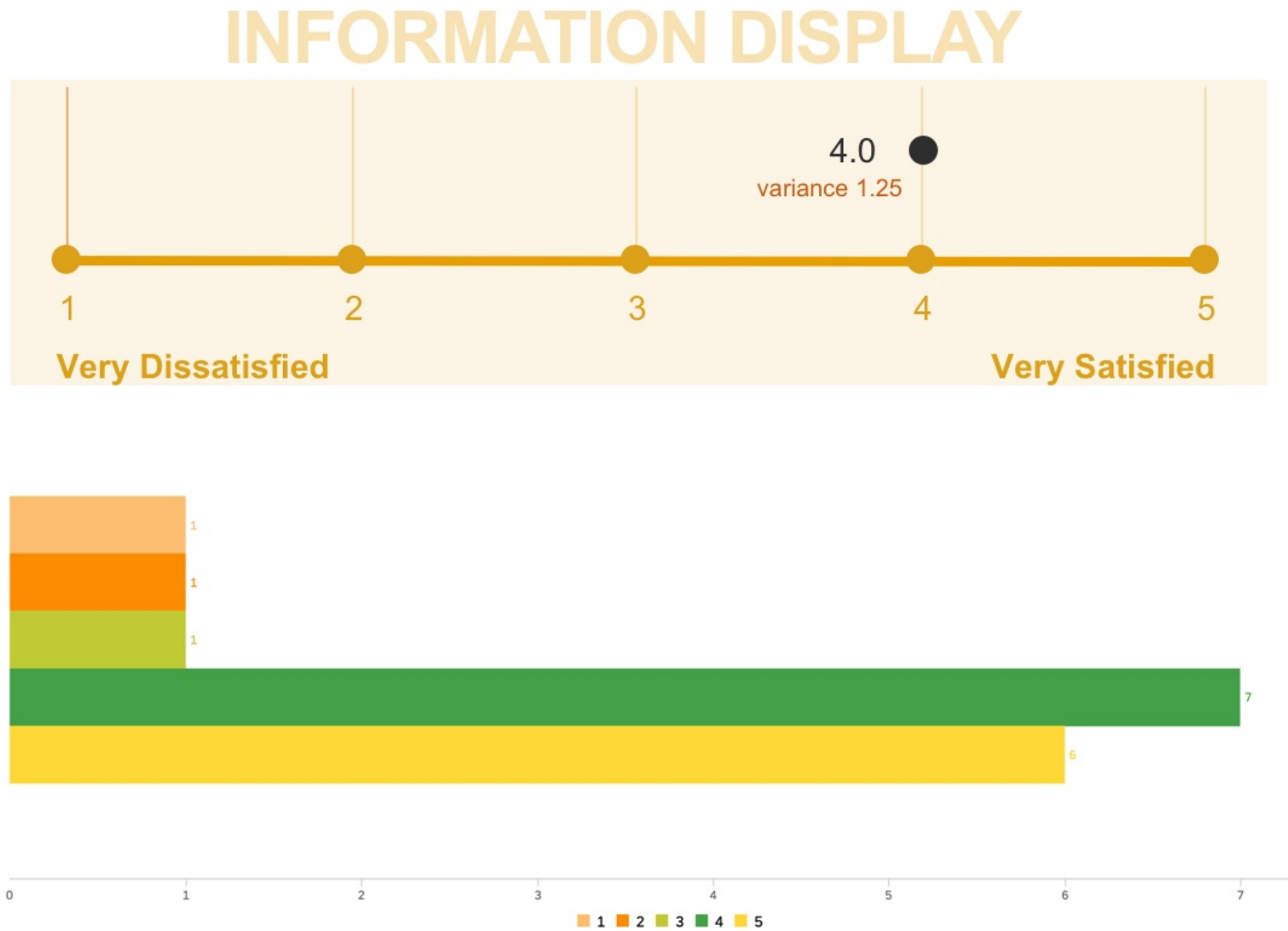
Question 3. Understanding of Usage



Feedback:

1) The video has explained everything clearly to participants.

Question 4. Information Display



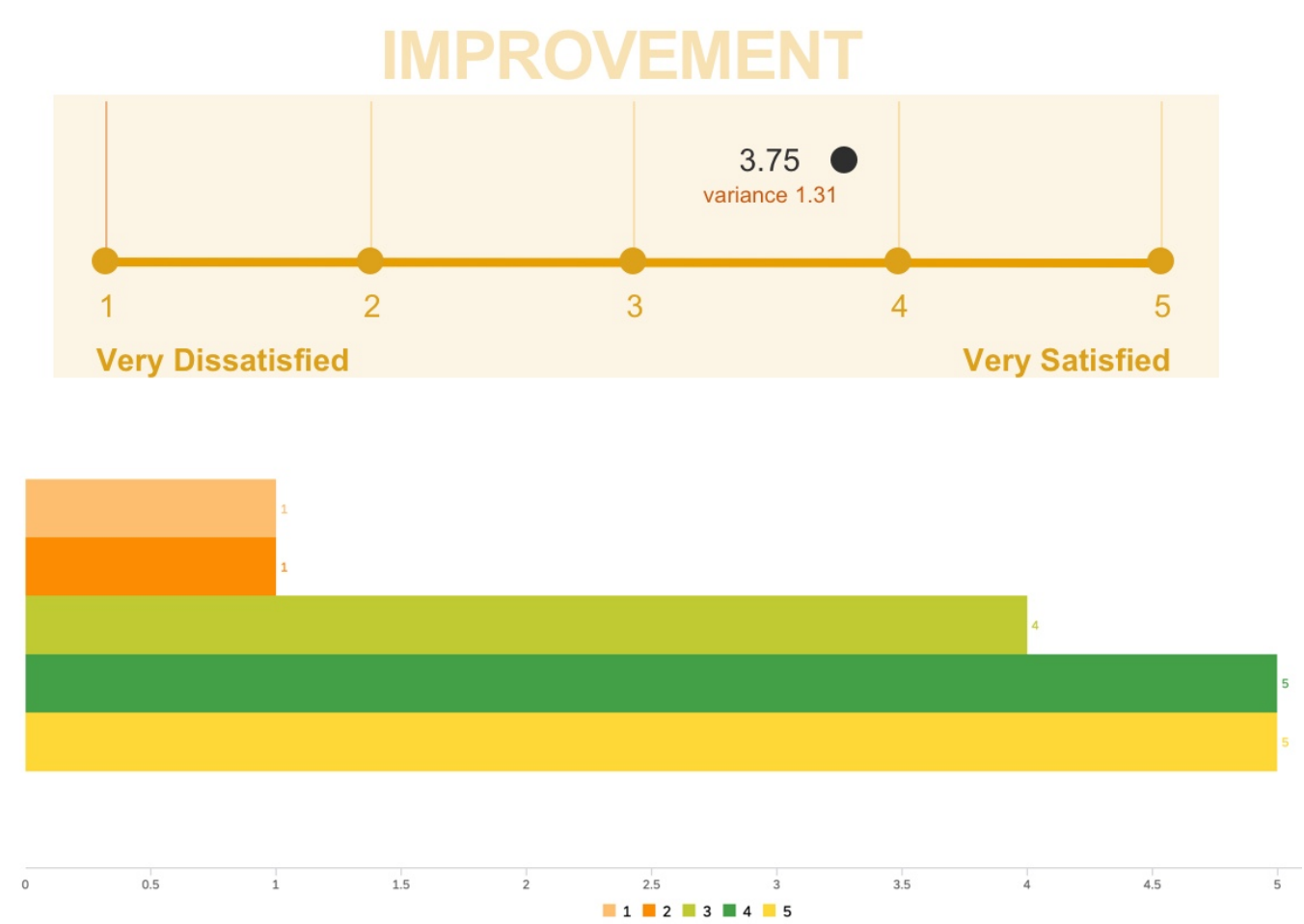
Feedback:

1) There were three participants scored under 4. Below are their comments:

- "My biggest concern is how the wrist band will feel to wear and how easily I would be able to feel and detect the different signals."
- "Not knowing how the vibration/signal would feel while actively riding makes me pause."
- "It looks good on paper. Would like to do the field test to determine if vibrations will work."

These three participants had a concern about the vibrations. They suggested us to do further study on finalizing the vibration design and testing the efficiency.

Question 5. Improvement of Road Safety



Question 6. Users' Thoughts on CycSight

"I really like the idea but I wouldn't wear a wristband since I already wear a watch... if it could be an armband or something more sleek, I would wear it."

"The video was not that clear about how the CycSight warns the rider to avert the car."

"It is not clear to me what material the wrist is made of. I am a long-distance cyclist, so I have a tool bag behind the seat. The camera may not be good fit. 3. How long is the battery life as I can ride 6-7 hours. But the concept is awesome."

"I think it would be helpful if the radar detector also flashed a red light so it could double as a radar detector and as a light alerting car to the presence of the bicycle. My biggest concern is how the wrist band will feel to wear and how easily I would be able to feel and detect the different signals. I look forward to further info on this product. thank you."

"I like the concept in terms of a warning signal from the rear. Accidents happen in biking from unexpected directions not just the rear. But this is still a cool device."

"Unsure if it's easy to detect colors on bright days while riding."

"This isn't as appealing to me. I've been riding over 10 years (avg 100-150 miles a week) and never have problem riding with cars."

"It's a start, the seat post design can be obstructed whereas it may be best to create it to clamp onto the seat area or the back of a helmet- , a speeding car will not save you ... too many " what if's" but there is room for improvement , lastly the wrist band looks small as the woman in the video has small wrist... that also can be improved."

"What a great invention! It may be beneficial to Deaf people. FYI, we do not call ourselves hearing impaired. It sounds like we have problems with hearing. Instead, use Deaf and Hard of Hearing. Thanks!"

"The unit as designed would interfere with what's already on my seat post- my rear light, or my trailer hitch, or my seat bag (depending on bike). The wrist unit needs to be integrated into something else- i already have my Road ID and GPS watch there. The idea is good but the design is as if we did not have anything else in the bike. In addition- the seat post radar might not be the most effective for those of us who commute and ride with panniers."

"Not knowing how the vibration/signal would feel while actively riding makes me pause. If I could clearly distinguish vibration for each zone, this would be better than currently having to look down to check status of traffic behind."

"I have the Garmin rear view for my GPS Edge already. Look at the GPS Edge's dots that cars are behind me. It will be great to wear the wrist band that I can feel vibration too but I do not feel comfortable to look at my wrist band due to my safety issue."

“May I recommend integrating radar with flashing light to warn drivers from behind they are being too close. Flashing light could replicate same settings as wristband to alert drivers behind they are approaching biker. Instead of having radar just communicate to the rider, the radar can communicate to both the rider and the driver.”

“I think it is the wrong approach and we need to build more bike lanes instead. Places are Amsterdam are safe for bicyclists not because they use fancy technology but because they create safe spaces for biking.”

“It looks good on paper. Would like to do the field test to determine if vibrations will work. Durability? Endurance? Reliability?”

5.2.4 Insights

We could tell that unlike user test participants, these long-term cyclists were more focused on the practical use of CycSight. Their biggest concern was the vibration. How well would it work? This is also my biggest concern. My next step would be investigating the vibration intensity range, finding out efficient vibration patterns for cyclists, and testing the efficiency.

Two users mentioned integrating a taillight in CycSight. By finding a better illuminant material, this could be a very feasible direction.

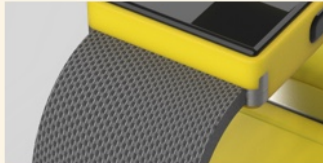
In my opinion, the most feasible direction for CycSight in the future is a professional sports band for cyclists. By adding more functions to it, users can take a CycSight instead of wearing several assistive devices.

CONCLUSION

6.1 Limitations & Potential

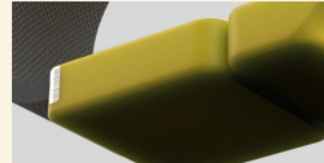
PHYSICAL DESIGN LIMITATIONS & POTENTIAL

Wristband



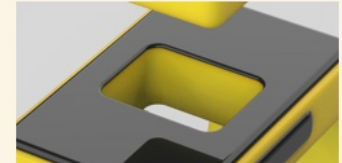
Belt Buckle

Current buckle design is hard to fasten with one hand.



Battery

There's no necessity to separate the battery from wristband main body.



Radar Detector

We could use spring mechanism to hold the radar detector. By pushing the radar, the mechanism will pop the radar out and fill the hole.

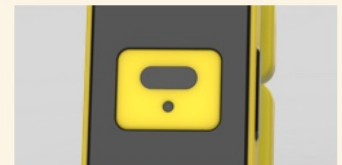
Clamp



Potential Direction

By generating electricity from cyclist's motion, the calmp could be a charger for the radar.

Radar Detector



Potential Direction

By finding a better luminescent materials, we could combine the radar detector with taillight.

INTERFACE DESIGN LIMITATIONS & POTENTIAL

Wristband



Vibrations

We need further research to find out the efficient vibration patterns and proper intensity range.



Potential Direction

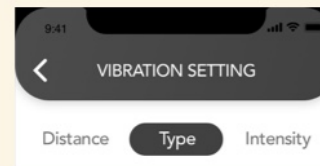
We could add more functions like heart beat monitoring or realtime GPS tracking to the wristband interface.

App



Device Connection

We should let users connect all devices with simply one click.



Guidance

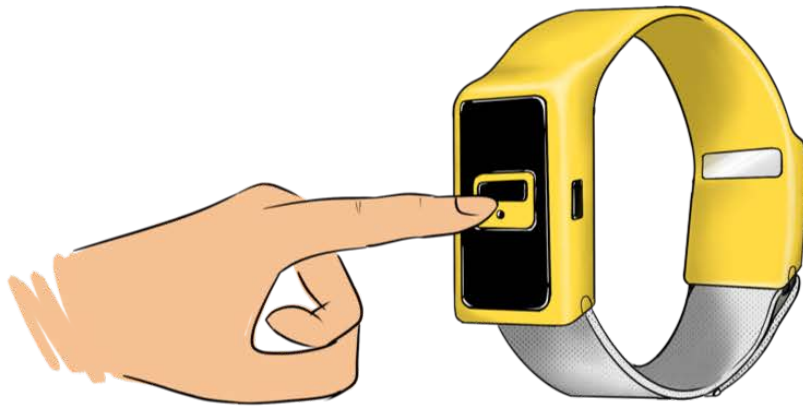
When users feel confused about the interface, we need to provide them a guidance.



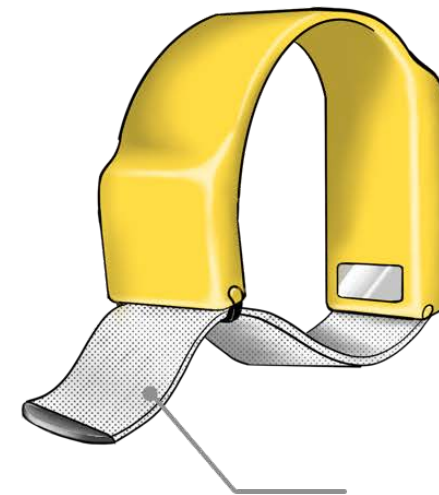
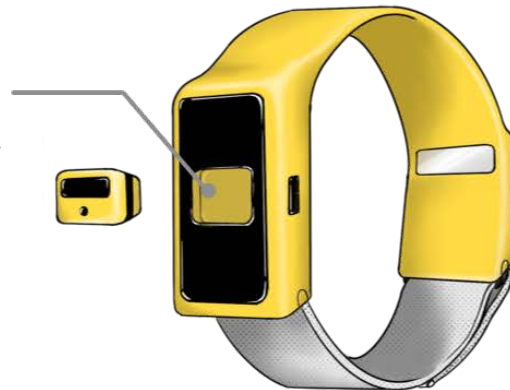
Unit Conversion

To help users better understand the distance, we shall let them convert the unit based on habits.

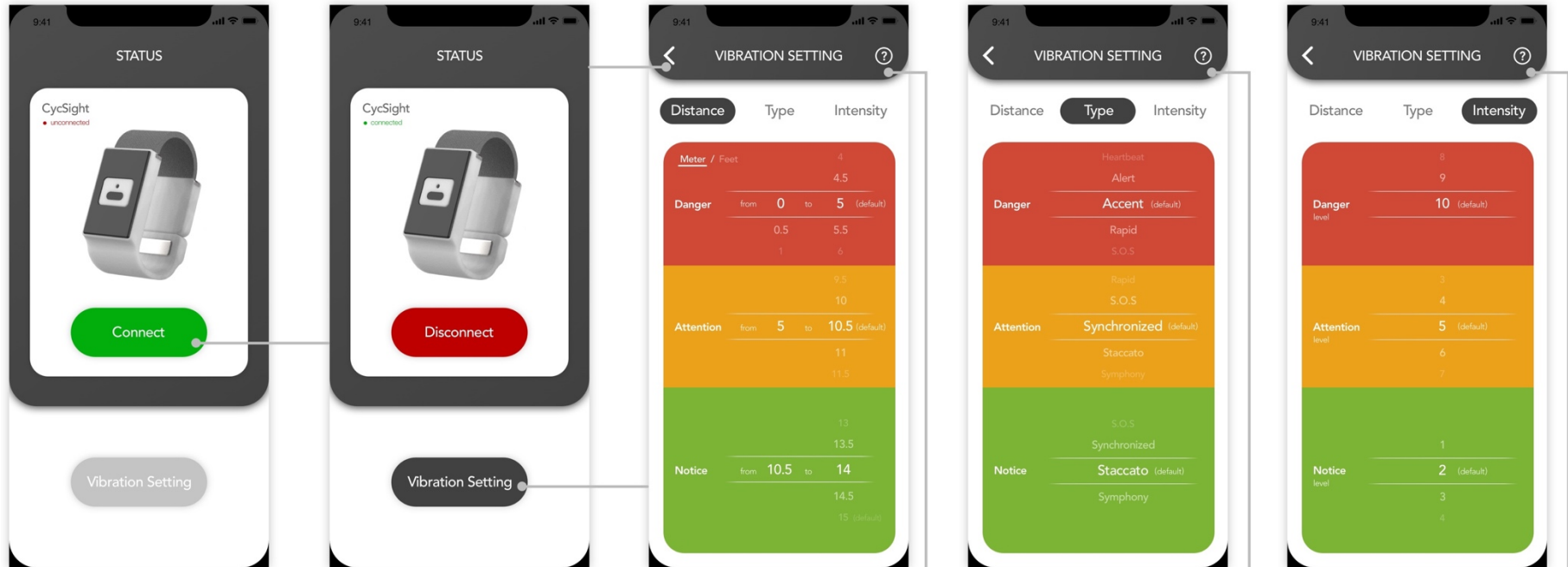
6.2 Revised Design



When users push the radar,
the spring mechanism
behind will pop the radar up.

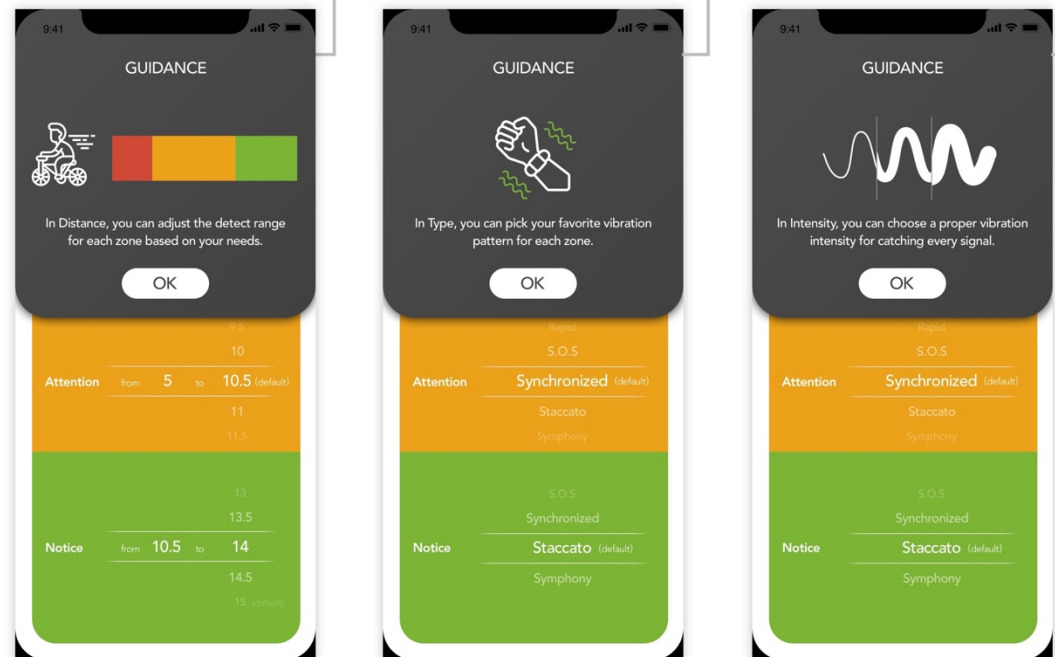


The Nylon loop belt allows
users to adjust freely.



With simple one click, users can connect CycSight to the their phones.

Users can converse units by their needs. When they get confused about the function, Guidance will always be there helping.



6.3 Next Step

All limitations have been fixed in the revised design concept except for the vibration. Our next step is investigating the proper vibration intensity range and the most efficient vibration patterns.

I plan to recruit 12 volunteers (6 males). They will be asked to ride on the spinning bike and watch a video during the test. The purpose is to simulate their daily usage scenario. Stimuli will be placed on both of their wrists. By comparing their detection rate and response time, I will be able to find out what vibration pattern is the easiest to detect and what's the proper intensity range for cyclists.

After finalizing the vibration design, we will test out the efficiency of CycSight in real condition.

ACKNOWLEDGMENT

I would like to thank Prof. Jon Sanford, my advisor, for all the patience and guidance he provided. My grateful thanks are also extended to Prof. Leila Aflatoony and Prof. Sang Leigh for their constructive suggestions and insight.

I would like to thank all the participants from TechSAGE and Deaf Seniors of America Association. I couldn't finish my research without their valuable feedback. Further thanks to my friends who helped me conduct my research and shoot the video.

Finally, special thanks to my family for their support.

REFERENCES

- [1] Marion Hersh, James Ohene-Djan & Saduf Naqvi. (2010). Investigating Road Safety Issues and Deaf People in the United Kingdom: An Empirical Study and Recommendations for Good Practice. *Journal of Prevention & Intervention in the Community*, 38:4, 290-305, DOI: 10.1080/10852352.2010.509021
- [2] Franklin, Patricia & Bourquin, Eugene. (2000). Picture this: A pilot study for improving street crossings for deaf-blind travelers. *RE:view*, v31 n4 p173-79 Win 2000, ISSN: ISSN-0899-1510
- [3] James Ohene-Djan, Marion Hersh & Saduf Naqvi. (2010). Road Safety and Deaf People: The Role of the Police. *Journal of Prevention & Intervention in the Community*, 38:4, 316-331, DOI: 10.1080/10852352.2010.509023
- [4] Governors Highway Safety. (2018). Bicyclist and Pedestrian Safety. Retrieved from <https://www.ghsa.org/issues/bicyclists-pedestrians>
- [5] Governors Highway Safety. (2015). Everyone Walks. Understanding and Addressing Pedestrian Safety. Retrieved from <https://www.ghsa.org/resources/everyone-walks15>
- [6] Governors Highway Safety. (2017). A Right to the Road: Understanding & Addressing Bicyclist Safety. Retrieved from <https://www.ghsa.org/resources/bicyclist-safety2017>

- [7] Justin M. Owen. (2008). Quiet Vehicle Avoidance Systems for Blind and Deaf-Blind Pedestrians. VCU Bioinformatics and Bioengineering Summer Institute Research Proposal: Summer 2008
- [8] Ce Zhong, Jiajin LI, Xiaotong Sun. (2017). A'Design Award & Competition: Safety Cycling Riding Helme. Retrieved from <https://competition.adesignaward.com/design.php?ID=58327>
- [9] World Health Organization. (2019). Deafness and Hearing Loss. Retrieved from <https://www.who.int/news-room/fact-sheets/detail/deafness-and-hearing-loss>
- [10] User Centered Design. (2018). Retrieved from <https://www.interaction-design.org/literature/topics/user-centered-design>
- [11] Roy, R., & Baxter, D. (2009). Product-service systems. Journal of Engineering Design, 20(4), 327-328. doi:10.1080/09544820903149271
- [12] Idin Karuei, Karon E. MacLean, Zoltan Foley-Fisher†, Russell MacKenzie, Sebastian Koch, & Mohamed El-Zohairy. (2011). Detecting Vibrations Across the Body in Mobile Contexts. CHI '11: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. May 2011 Pages 3267–3276.
- [13] Self-Driving Car Technology: How Do Self-Driving Cars Work? | Landmark Dividend <https://www.landmarkdividend.com/self-driving-car/>

[14] Battery reference: <https://www.ifixit.com/Teardown/AirPods+Teardown/75578>

[15] Haptic engine reference:

<https://www.ifixit.com/Teardown/Apple+Watch+Series+4+Teardown/113044>

[16] Radar transceiver system reference: <https://www.ti.com/product/AWR1642>

<https://www.ti.com.cn/tool/cn/IWR1642BOOST>

[17] Bluetooth module reference:

https://www.tdk.com/corp/en/news_center/press/20140212771.htm

[18] Linear voltage regulator reference:

<https://www.ti.com/document-viewer/LP3990-Q1/datasheet/abstract#snvs2510025>

[19] Mini LED screen reference:

<https://www.phoenixdisplay.com/product/color-displays/pdi09601a-v3/>

[20] Mini LED bulb reference: https://lighthouseleds.com/5mm-led-white-ultra-bright-15-000-mcd.html?gclid=Cj0KCQjw0Mb3BRCaARIsAPSNgpUrK_YUMnZH8oSq4s6mvPMnEEXszu4y6K-titXit-jNIRctzr8ldLYaApxsEALw_wcB

[21] Spandex reference: <https://en.wikipedia.org/wiki/Spandex>

[22] Seat post clamp size reference:

https://www.urbanbiketech.com/product/pitlock/accessories/saddle-clamp-seatpost-clamp/?attribute_seat-collar-size=28.6mm&attribute_seat-collar-color=black&campaignid=8005799888&adgroupid=85557586994&feeditemid=&targetid=pla-293946777986&loc_interest_ms=&loc_physical_ms=9010791&matchtype=&network=g&device=c&devicemodel=&creative=395395505927&keyword=&placement=&target=¶m1=¶m2=&adposition=&gclid=CjwKCAjwltH3BRB6EiwAhj0lUMfil4nx56wb9XtaIFw6w9gaxyuzMfjyCDrRQp1q_9abfh9JD3Yo2BoCHzYQAvD_BwE

Picture Attribute

Icons made by [Freepik](https://www.flaticon.com/authors/freepik "Freepik")
from [www.flaticon.com](https://www.flaticon.com/ "Flaticon")

Icons made by [Freepik](https://www.flaticon.com/authors/freepik "Freepik")
from [www.flaticon.com](https://www.flaticon.com/ "Flaticon")

Icons made by [Freepik](https://www.flaticon.com/authors/freepik "Freepik")
from [www.flaticon.com](https://www.flaticon.com/ "Flaticon")

Icons made by [srip](https://www.flaticon.com/authors/srip "srip") from [www.flaticon.com](https://www.flaticon.com/ "Flaticon")

Icons made by [prettycons](https://www.flaticon.com/authors/prettycons "prettycons")
from [www.flaticon.com](https://www.flaticon.com/ "Flaticon")

Icons made by [Freepik](https://www.flaticon.com/authors/freepik "Freepik")
from [www.flaticon.com](https://www.flaticon.com/ "Flaticon")

Icons made by Eucalyp
from www.flaticon.com

Icons made by Freepik
from www.flaticon.com

Icons made by Nhor
Phai from www.flaticon.com

Icons made by Becris from
 www.flaticon.com

Icons made by Freepik
from www.flaticon.com

Icons made by Eucalyp
from www.flaticon.com

Icons made by Freepik
from www.flaticon.com

APPENDIX

Full Consent Form

You are being asked to volunteer your time, approximately 10 minutes, to complete an anonymous online survey.

The qualifications to take this survey include having different degrees of hearing impairments. The purpose of this form is to inform you, the survey taker, about the tasks that will be asked to be completed and to inform you about your rights as a research volunteer.

Please feel free to ask any questions that you may have about this research study and what you will be asked to do. Thank you for your interest in participating in this research study. Our work could not be completed without your help.

What Am I Being Asked To Do?

You are being asked to be a volunteer in a research study. In the following step, you will need to finish an online survey. You can find the key information of the study in this consent form to help you decide if you would like to participate. Your participation is voluntary.

What Is This Study About and What Procedures Will You be Asked to Follow?

This study is primarily about identifying road safety issues existing in deaf pedestrians and cyclists' daily life. You will need to click on the check box at the end of this page and submit the consent. You will be automatically directed to an online questionnaire. The questionnaire will take you approximate 10 minutes to complete. You will be asked to finish this questionnaire.

Are There Any Risks or Discomforts you Might Experience by Being in this Study?

Other than recalling your road safety issue and experience that will cause mental pressure, the risks are no greater than those associated with using a computer or mobile device. If you may feel stressful of the potential risks listed above, you should not be in this study. All information collected from the survey will be anonymous.

What Are the Reasons You Might Want to Volunteer For This Study?

You are not likely to benefit in any way from joining this study. However, your participation in the study will assist researchers in better understanding deaf community's daily challenges, and improve the walking and cycling experience for people with hearing impairment.

Do You Have to Take Part in the This Study?

It is fully your decision if you wish to be in this study or not. If you choose not to participate, or choose to participate and later determine you no longer wish to, you will not lose any rights, services, or benefits as a result of your withdrawal. The study is completely voluntary.

CONSENT DOCUMENT FOR ENROLLING ADULT PARTICIPANTS IN A RESEARCH STUDY

Georgia Institute of Technology

Project Title: Deaf Pedestrians and Cyclists' Road Safety Issue Investigation

Investigators: *Jon Sanford, Professor, School of Industrial Design, Georgia Tech*

Siran Liao, Master's Candidate School of Industrial Design, Georgia Tech

Protocol and Consent Title: 08/29 v4 Deaf Pedestrians and Cyclists' Road Safety Issue Investigation Consent Form

You are being asked to be a volunteer in a research study because you are with hearing impairment. The purpose of this form is to tell you about the tasks you will be asked to complete and to inform you about your rights as a research volunteer. Feel free to ask any questions that you may have about this research study and what you will be asked to do. Thank you for your interest in participating in this research study. Our work could not be completed without your help.

Purpose:

The purpose of this project is to investigate and improve the road safety issue of pedestrians and cyclists who have a hearing loss. This study aims to enable the investigator to better understand what information people with hearing loss need to feel safer when crossing the road or riding a bicycle on a busy street. 25-200 subjects will be invited to take part in this study.

Exclusion/Inclusion Criteria:

Participants in this study must be people who have different degrees of hearing impairment and must age 18 or above. People who cannot make decisions independently will not be involved in this study.

If you are located in a European Union (EU) country, you are not permitted to participate in this study due to the General Protection Data Regulation (GDPR).

Procedures:

If you decide to be in this study, you will be asked to click on the check box at the end of this page and submit the consent. You will be automatically directed to an online questionnaire. The questionnaire will take approximately 10 minutes to complete. The questionnaire is designed to better understand your daily road safety issue. Some questions are about your walking experience as a pedestrian while others are about your experience as a cyclist.

Risks or Discomforts:

Other than recalling your road safety issue and experience that will cause mental pressure, the risks are no greater than those associated with using a computer or mobile device.

Benefits:

You are not likely to benefit in any way from joining this study. We hope to learn more about your everyday challenges and how you handle them. We hope that findings from this study will help increase awareness of these challenges and create interventions that can improve deaf community's walking and cycling experience.

Compensation to You:

There is no compensation for participating in this study.

Use of Photographs, Audio, or Video Recordings:

There won't be any photographs, audio, or video recorded during the study.

Confidentiality:

The following procedures will be followed to keep your personal information confidential in this study: Your privacy will be protected to the extent required by law. To protect your privacy, no personal information that

could be used to identify you will be collected. The only personal data collected will be your age group. To protect your information, data will be collected using Qualtrics, a secure online survey application. Individual information will be kept under a code number rather than by name, and code numbers will not be associated with any facts that might point to you. All the digital information will be stored in a pass-coded folder on a secure GA Tech server, and unless you give specific consent otherwise, only study staff will be allowed to look at them. Your name and any other fact that might point to you will not appear when results of this study are presented or published.

Even if all identifiers have been removed from your data, your data will not be used or distributed for the purposes of future research. The Georgia Institute of Technology IRB, the Office of Human Research Protections, and/or the Food and Drug Administration may look over study information during required reviews.

When you complete the study questionnaires online, you should be aware that it is not being run from a 'secure' https server of the kind typically used to handle credit card transactions, so there is a small possibility that unauthorized third parties such as computer hackers could view responses. In general, the web page software will log as header lines the IP address of the machine you use to access this page, e.g., 102.403.506.807, but otherwise, no other information will be stored unless you explicitly enter it.

Costs to You:

There are no costs to you, other than your time, for being in this study.

Questions about the Study:

If you have any questions about the study, you may contact:

Siran Liao, (404) 547-9146, siranliao@gatech.edu

Questions about your Rights as a Research Participant

- Your participation in this study is voluntary. You do not have to be in this study if you don't want to be.

- You have the right to change your mind and leave the study at any time without giving any reason and without penalty.
- Any new information that may make you change your mind about being in this study will be given to you.
- You will be given a copy of this consent form to keep.
- You do not waive any of your legal rights by signing this consent form.

If you have any questions about your rights as a research participant, you may contact

Ms. Melanie Clark, Georgia Institute of Technology
Office of Research Integrity Assurance, at (404) 894-6942.”

or

Ms. Kelly Winn, Georgia Institute of Technology
Office of Research Integrity Assurance, at (404) 385- 2175.



If you click here, it means that you have read (or have had read to you) the information given in this consent form, and you would like to be a volunteer in this study.

Please submit the consent and you will be automatically directed to the online questionnaire.

Research Questionnaire

1. What's your age group?

- a) 18-30
- b) 31-50
- c) 51-70
- d) Over 70

2. When walking by yourself, please rate how safe will you feel in the following situations:

a) Crossing a busy street at a four-way intersection with no traffic signals or crosswalks.

1) very unsafe 2) unsafe 3) normal 4) safe 5) very safe

b) Crossing a busy street at a four-way intersection with stop lights only.

1) very unsafe 2) unsafe 3) normal 4) safe 5) very safe

c) Crossing a busy street at a four-way intersection with stop signs only.

1) very unsafe 2) unsafe 3) normal 4) safe 5) very safe

d) Crossing a busy street at a four-way intersection with crosswalks only.

1) very unsafe 2) unsafe 3) normal 4) safe 5) very safe

3. What type of information is important for you to feel safe when crossing busy streets? Please choose all the options you need.

- a) the direction of travel of all vehicles around you
- b) the direction of travel of only the vehicle closest to you
- c) the speed of all vehicles around you
- d) the speed of only the vehicle nearest to you
- e) if vehicles near you are slowing down
- f) the type of vehicle closest to you (e.g., bus, tractor-trailer, passenger car, motorcycle, bicycle)
- g) the distance between you and all of the vehicles around you
- h) the distance between you and the vehicle closest to you
- i) the timing of the traffic lights
- j) how much time you have to cross the street
- k) how long it will take you to cross the street given the number of people around you
- l) Other:

4. Do you ride a bicycle on public streets or sidewalks.

a) Yes If you answered yes, that you ride a bicycle on public streets or sidewalks, go to question 5.

b) No If you answered NO, that you do not ride a bicycle on public streets or sidewalks, you have completed the survey.

5. When riding a bicycle, please rate how safe will you feel in the following situations:

a) Riding a bicycle on a busy street with no bike lanes.

1) very unsafe 2) unsafe 3) normal 4) safe 5) very safe

b) Riding a bicycle on a busy street with bike lanes that do not have barriers.

1) very unsafe 2) unsafe 3) normal 4) safe 5) very safe

c) Riding a bicycle on a busy street with bike lanes with physical barriers.

1) very unsafe 2) unsafe 3) normal 4) safe 5) very safe

d) Riding a bicycle on a busy street with sharrows (shared lanes) only.

1) very unsafe 2) unsafe 3) normal 4) safe 5) very safe

6. What type of information is important for you to feel safe when cycling on busy streets? Please choose all the options you need.

a) the speed of all vehicles around you

b) the speed of vehicles crossing intersections in front of you

c) the speed of only vehicles behind you

d) the type of vehicle behind you (e.g., bus, tractor trailer, passenger car, motorcycle, bicycle)

e) the distance between you and all of the vehicles around you

f) the distance between you and all of the vehicles behind you

g) the distance between you and all of the vehicles around you

h) the distance between you and the closest vehicle behind you

i) the distance to the next intersection that you will ride across

j) the lane that the closest vehicle behind you is in

k) Other:

7. When riding a bicycle, do you have any tools to help you monitor the traffic behind? (e.g. mirrors or monitors)

a) Yes, I have. Please write down your method.

b) No, I don't.

Research Questionnaire Report

1. What's your age group?

#	Answer	%	Count
2	a) 18-30	5.56%	1
3	b) 31-50	44.44%	8
4	c) 51-70	16.67%	3
5	d) Over 70	33.33%	6
	Total	100%	18

2. When walking by yourself, please rate how safe will you feel in the following situations:

1) Crossing a busy street at a four-way intersection with no traffic signals or crosswalks.

#	Question	a) 18-30		b) 31-50		c) 51-70		d) Over 70		Total
1	very unsafe	0.00%	0	50.00%	4	25.00%	2	25.00%	2	8
4	unsafe	16.67%	1	33.33%	2	16.67%	1	33.33%	2	6
5	normal	0.00%	0	50.00%	1	0.00%	0	50.00%	1	2
6	safe	0.00%	0	0.00%	0	0.00%	0	100.00%	1	1
7	very safe	0.00%	0	100.00%	1	0.00%	0	0.00%	0	1

2) Crossing a busy street at a four-way intersection with stop lights only.

#	Question	a) 18-30		b) 31-50		c) 51-70		d) Over 70		Total
1	very unsafe	0.00%	0	33.33%	1	33.33%	1	33.33%	1	3
4	unsafe	20.00%	1	60.00%	3	0.00%	0	20.00%	1	5
5	normal	0.00%	0	0.00%	0	33.33%	1	66.67%	2	3
6	safe	0.00%	0	50.00%	2	25.00%	1	25.00%	1	4
7	very safe	0.00%	0	66.67%	2	0.00%	0	33.33%	1	3

3) Crossing a busy street at a four-way intersection with stop signs only.

#	Question	a) 18-30		b) 31-50		c) 51-70		d) Over 70		Total
1	very unsafe	0.00%	0	50.00%	2	25.00%	1	25.00%	1	4
4	unsafe	0.00%	0	100.00%	1	0.00%	0	0.00%	0	1
5	normal	11.11%	1	22.22%	2	22.22%	2	44.44%	4	9
6	safe	0.00%	0	66.67%	2	0.00%	0	33.33%	1	3
7	very safe	0.00%	0	100.00%	1	0.00%	0	0.00%	0	1

4) Crossing a busy street at a four-way intersection with crosswalks only.

#	Question	a) 18-30		b) 31-50		c) 51-70		d) Over 70		Total
1	very unsafe	0.00%	0	50.00%	1	50.00%	1	0.00%	0	2
4	unsafe	10.00%	1	30.00%	3	20.00%	2	40.00%	4	10
5	normal	0.00%	0	50.00%	2	0.00%	0	50.00%	2	4
6	safe	0.00%	0	100.00%	1	0.00%	0	0.00%	0	1
7	very safe	0.00%	0	100.00%	1	0.00%	0	0.00%	0	1

3. What type of information is important for you to feel safe when crossing busy streets? Please choose all the options you need.

#	Answer	%	Count
3	c) the speed of all vehicles around you	16.47%	14
9	i) the timing of the traffic lights	15.29%	13
1	a) the direction of travel of all vehicles around you	14.12%	12
10	j) how much time you have to cross the street	12.94%	11
7	g) the distance between you and all of the vehicles around you	9.41%	8
5	e) if vehicles near you are slowing down	8.24%	7
6	f) the type of vehicle closest to you (e.g., bus, tractor-trailer, passenger car, motorcycle, bicycle)	7.06%	6
8	h) the distance between you and the vehicle closest to you	7.06%	6
11	k) how long it will take you to cross the street given the number of people around you	5.88%	5
2	b) the direction of travel of only the vehicle closest to you	2.35%	2
4	d) the speed of only the vehicle nearest to you	1.18%	1
12	l) Other:	0.00%	0
	Total	100%	85

4. When riding a bicycle, please rate how safe will you feel in the following situations:

1) Riding a bicycle on a busy street with no bike lanes.

#	Question	a) 18-30		b) 31-50		c) 51-70		d) Over 70		Total
1	very unsafe	11.11%	1	44.44%	4	22.22%	2	22.22%	2	9
4	unsafe	0.00%	0	57.14%	4	0.00%	0	42.86%	3	7
5	normal	0.00%	0	0.00%	0	100.00%	1	0.00%	0	1
6	safe	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0
7	very safe	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0

2) Riding a bicycle on a busy street with bike lanes that do not have barriers.

#	Question	a) 18-30		b) 31-50		c) 51-70		d) Over 70		Total
1	very unsafe	14.29%	1	42.86%	3	14.29%	1	28.57%	2	7
4	unsafe	0.00%	0	55.56%	5	11.11%	1	33.33%	3	9
5	normal	0.00%	0	0.00%	0	100.00%	1	0.00%	0	1
6	safe	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0
7	very safe	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0

3) Riding a bicycle on a busy street with bike lanes with physical barriers.

#	Question	a) 18-30		b) 31-50		c) 51-70		d) Over 70		Total
1	very unsafe	50.00%	1	0.00%	0	50.00%	1	0.00%	0	2
4	unsafe	0.00%	0	0.00%	0	100.00%	1	0.00%	0	1
5	normal	0.00%	0	33.33%	2	0.00%	0	66.67%	4	6
6	safe	0.00%	0	60.00%	3	20.00%	1	20.00%	1	5
7	very safe	0.00%	0	100.00%	3	0.00%	0	0.00%	0	3

4) Riding a bicycle on a busy street with sharrows (shared lanes) only.

#	Question	a) 18-30		b) 31-50		c) 51-70		d) Over 70		Total
1	very unsafe	20.00%	1	60.00%	3	20.00%	1	0.00%	0	5
4	unsafe	0.00%	0	25.00%	2	12.50%	1	62.50%	5	8
5	normal	0.00%	0	75.00%	3	25.00%	1	0.00%	0	4
6	safe	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0
7	very safe	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0

5. What type of information is important for you to feel safe when cycling on busy streets? Please choose all the options you need.

#	Answer	%	Count
11	k) Other:	1.28%	1
10	j) the lane that the closest vehicle behind you is in	10.26%	8
9	i) the distance to the next intersection that you will ride across	11.54%	9
8	h) the distance between you and the closest vehicle behind you	6.41%	5
6	f) the distance between you and all of the vehicles behind you	8.97%	7
5	e) the distance between you and all of the vehicles around you	14.10%	11
4	d) the type of vehicle behind you (e.g., bus, tractor trailer, passenger car, motorcycle, bicycle)	8.97%	7
3	c) the speed of only vehicles behind you	6.41%	5
2	b) the speed of vehicles crossing intersections in front of you	8.97%	7
1	a) the speed of all vehicles around you	14.10%	11
	Total	100%	78

6. When riding a bicycle, do you have any tools to help you monitor the traffic behind? (e.g. mirrors or monitors)

#	Question	a) 18-30		b) 31-50		c) 51-70		d) Over 70		Total
1	a) Yes, I have. Please write down your method.	0.00%	0	40.00%	2	20.00%	1	40.00%	2	5
2	b) No, I don't.	7.69%	1	46.15%	6	15.38%	2	30.77%	4	13

All text answers are “mirror”.

Expert Review Report

1. How many years have you been cycling?

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	2. How many years have you been cycling?	1.00	3.00	2.75	0.56	0.31	16

2. How do you like the appearance of CycSight? On a scale of 1 to 5, please rate each component.

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	radar detector	2.00	5.00	4.06	1.03	1.06	16
2	wrist band	1.00	5.00	3.00	1.46	2.13	16
3	seat post clamp	1.00	5.00	4.00	1.22	1.50	16

3. Do you understand the usage of CycSight? On a scale of 1 to 5, please rate each component.

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	radar detector	3.00	5.00	4.63	0.60	0.36	16
2	wrist band	3.00	5.00	4.63	0.70	0.48	16
3	seat post clamp	4.00	5.00	4.81	0.39	0.15	16

4. How do you like the way (haptic + visual) CycSight express the information? On a scale of 1 to 5, please rate.

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	5. How do you like the way (haptic + visual) CycSight express the information? On a scale of 1 to 5, please rate.	1.00	5.00	4.00	1.12	1.25	16

5. Overall, do you think CycSight can improve hearing impaired cyclists' road safety? On a scale of 1 to 5, please rate.

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	6. Overall, do you think CycSight can improve hearing impaired cyclists' road safety? On a scale of 1 to 5, please rate.	1.00	5.00	3.75	1.15	1.31	16

6. Please give us your thoughts on CycSight. Any feedback is valuable.

“I really like the idea but I wouldn't wear a wristband since I already wear a watch... if it could be an armband or something more sleek, I would wear it.”

“The video was not that clear about how the CycSight warns the rider to avert the car.”

“It is not clear to me what material the wrist is made of. I am a long-distance cyclist, so I have a tool bag behind the seat. The camera may not be good fit. 3. How long is the battery life as I can ride 6-7 hours. But the concept is awesome.”

“I think it would be helpful if the radar detector also flashed a red light so it could double as a radar detector and as a light alerting cars to the presence of the bicycle. My biggest concern is how the wrist band will feel to wear and how easily I would be able to feel and detect the different signals. I look forward to further info on this product. thank you.”

“I like the concept in terms of a warning signal from the rear. Accidents happen in biking from unexpected directions not just the rear. But this is still a cool device.”

“Unsure if it's easy to detect colors on bright days while riding.”

“This isn't as appealing to me. I've been riding over 10 years (avg 100-150 miles a week) and never have problem riding with cars.”

“It's a start, the seat post design can be obstructed whereas it mane be best to creat it to clamp onto the seat area or the back of a helmet- , a speeding car will not save you ... too many “ what if's” but there is room for improvement , lastly the wrist band looks small as the woman in the video has small wrist... that also can be improved.”

“What a great invention! It may be beneficial to Deaf people. FYI, we do not call ourselves hearing impaired. It sounds like we have problems with hearing. Instead, use Deaf and Hard of Hearing. Thanks!”

“The unit as designed would interfere with what's already on my seat post- my rear light, or my trailer hitch, or my seat bag (depending on bike). The wrist unit needs to be integrated into something else- I already have my Road ID and GPS watch there. The idea is good but the design is as if we did not have anything else in the bike. In addition- the seat post radar might not be the most effective for those of us who commute and ride with panniers.”

“Not knowing how the vibration/signal would feel while actively riding makes me pause. If I could clearly distinguish vibration for each zone, this would be better than currently having to look down to check status of traffic behind.”

“I have the Garmin rear view for my GPS Edge already. Look at the GPS Edge's dots that cars are behind me. It will be great to wear the wrist band that I can feel vibration too but I do not feel comfortable to look at my wrist band due to my safety issue.”

“May I recommend integrating radar with flashing light to warn drivers from behind they are being too close. Flashing light could replicate same settings as wristband to alert drivers behind they are approaching biker. Instead of having radar just communicate to the rider, the radar can communicate to both the rider and the driver.”

“I think it is the wrong approach and we need to build more bike lanes instead. Places like Amsterdam are safe for bicyclists not because they use fancy technology but because they create safe spaces for biking.”

“It looks good on paper. Would like to do the field test to determine if vibrations will work. Durability? Endurance? Reliability?”

User Test Report

1. How do you like the appearance of CycSight? On a scale of 1 to 5, please rate each component.

#	Field	Minimum	Maximum	Mean	Variance	Count
1	radar detector	3.00	4.50	3.86	0.48	7
2	wrist band	3.50	5.00	4.07	0.20	7
3	seat post clamp	4.00	5.00	4.43	0.29	7

2. Do you understand how to wear/assemble CycSight? On a scale from 1 to 5, please rate each component.

#	Field	Minimum	Maximum	Mean	Variance	Count
1	radar detector	3.50	5.00	4.64	0.39	7
2	wrist band	3.50	5.00	4.57	0.37	7
3	seat post clamp	3.00	5.00	4.71	0.57	7

- 3. Now you are cycling on a busy street, the status of CycSight wristband is like the left picture (play vibration at the same time). Please describe the condition of the vehicle behind.**

Answer	%	Count
a) correct	100%	7
b) wrong	0%	0

- 4. Now you are cycling on a busy street, the status of CycSight wristband is like the right picture (play vibration at the same time). Please tell me which vehicle is closer to you?**

Answer	%	Count
a) correct	86.71%	6
b) wrong	14.29%	1

5. Task 1: Please connect CycSight to the app.

	User 1	User 2	User 3	User 4	User 5	User 6	Mean
Time (second)	3.70	5.29	4.64	9.97	5.4	5.45	5.74

6. Task 2: Please adjust the range of Danger Zone to 0 – 9 meters; adjust the range of Attention Zone to 9 – 17 meters.

	User 1	User 2	User 3	User 4	User 5	User 6	Mean
Time (second)	14.28	15.63	17.87	18.81	17.60	12.44	16.11

7. Task 3: Please adjust the vibration type of Attention Zone to ‘Quick’; adjust the vibration type of Notice Zone to ‘Bamboo’.

	User 1	User 2	User 3	User 4	User 5	User 6	Mean
Time (second)	20.20	28.85	20.30	15.61	9.76	12.39	16.19

8. Task 4: Please adjust the vibration intensity of Danger Zone to level 14; adjust the vibration intensity of Notice Zone to level 9.

	User 1	User 2	User 3	User 4	User 5	User 6	Mean
Time (second)	12.70	10.62	7.41	4.50	4.42	9.11	8.13

9. How do you like the UI? On a scale from 1 to 5, please rate. (1 = very dissatisfied; 5 = very satisfied)

Minimum	Maximum	Mean	Variance	Count
4.00	5.00	4.46	0.26	7

10.How do you like the function of this app? On a scale from 1 to 5, please rate. (1 = very dissatisfied; 5 = very satisfied)

Minimum	Maximum	Mean	Variance	Count
4.50	5.00	4.69	0.14	7

11.Overall, how do you like CycSight? On a scale from 1 to 5, please rate. (1 = very dissatisfied; 5 = very satisfied)

Minimum	Maximum	Mean	Variance	Count
3.00	4.50	4.07	0.29	7

